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## THE FRANKLIN INSTITUTE.

### The William J. Hammer Collection of Incandescent Electric Lamps.

[*Being the Report of the Committee on Science and the Arts on the Historical Collection of Incandescent Electric Lamps made and Exhibited at the St. Louis Exposition of 1904, by Mr. William J. Hammer. Sub-Committee: C. J. Reed, Chairman; Carl Hering, Thomas Spencer.*]

[No. 2385.]

The Franklin Institute, acting through its Committee on Science and the Arts, investigating the merits of the collection of more than 1000 incandescent electric lamps, made by Mr. William J. Hammer, of New York, reports as follows:—

This collection of lamps, made during a period covering more than a quarter of a century, may truly be said to represent the "History of the Art." This history embodied in this collection is not a history that could have been recorded in words, that could be duplicated by any process or reproduced if destroyed.

It is the result of the most vigilant and systematic efforts on the part of the collector during the past twenty-five years and over, not only in the United States, but in many countries of Europe during his various sojourns abroad, which covered altogether about six years. The collection was started in 1879, when, at the beginning of Mr. Edison's work, Mr. Hammer had charge, in Mr. Edison's laboratory at Menlo Park, N. J., of certain tests and records relative to the life, efficiency and general characteristics of the Edison lamps. Mr. Hammer was afterwards appointed electrician of the first Edison lamp factory at Menlo Park and here he obtained much of the material forming the earlier part of the collection.

At a great personal outlay of time, labor, thought, and money, he has secured material showing practically every step in its development, from Edison's early platinum thermostatic-regulator lamp, platinum-iridium spiral lamps, multiple foil platinum lamps, oxide-of-zirconium lamps of 1878, up to the most modern type of lamps. The collection embraces, not only the entire art under Edison, dating from his first commercial lamp, the famous "paper horse-shoe" lamp of 1879, his plumbago, graphite, bamboo, and other vegetable filament lamps, but also the work of Edison's contemporaries here and abroad from this early period down to the present time, including the following:—

Swan, also Edison-Swan, Ediswan, Swan United and Brush-Swan types, Lane-Fox, Maxim, Weston, DeChangy, Sawyer, Lodyguine molybdenum, Cruto, Gatehouse, Kurtzgen, Swinburne, Crookes, Bernstein, Müller, Boehm, Gerard, Latimer, Rogers, Opperman, Diehl, Thompson, Stanley-Thompson, Thomson-Houston, Remington, British Electric, Akester, Alexander, Richter, Schuyler, Duplex Co., Siemens & Halske, Siemens Bros., Greinert & Friederich, Vitrite-Luminoid, Sawyer, Sawyer-Man, Nothomb, Hochhausen, Hammer, Sun, Franklin, Schmauser, Greiner, Schaefer, Jenny, White, Excelsior, Belgian, and includes also the more modern development under Ganz & Co., United Electric, Von Choate, Guest, Phoenix, Gilmore, Sun-Star, Solar, Monarch, Colonial, Economy, Brilliant, Tipless, Sterling, Comet, Capital, Goebel, Von Kamerer, Dubligo, Elblight, Zenith, American, A. E. G., New Universal, "Watt," Hardy, Trilight, Fostoria, Malden, Esco, Meriden, T. A. Edison, Jr., Tipless, "Guage," Premier, Miller, Buckeye, Femco, S. A. C., Sunbeam, Packard, Perkins, Boston, Westinghouse, Novak, Columbia, Seel, Pray, A. B. C., DeKhotinsky, Zugh, Peerless, Orient, Banner, Downward, Hylo, Economical, An-

chor, Munder, Brian-Marsh, Empire, Fabius-Henrion, Compagnie Centrale d'Electricite, Compagnie General des Lampes, Larnaude, Zurcher, Gelnhousen, Pintsch, Bayeische, Goosens-Pope, Phillips, Kremenetzsky, Schonlah & Scharfs, Clerici, Vereingite E. A. G., Strum, Heany tungsten, Talmont, Adams, Bagnal, Hammer "Radium", Pollard, Imperial, Thowles, Shelby, Kyle, Zalinsky, Kentucky, Star, O'Brien, Sunshine, Germania, Nernst, Moore, Osmium, Aueros, Osmi, Langhans, Crawford-Voelker, Tantalum, New Edison Graphitic Lamp, Kuzel, etc.

In nearly all cases the lamps constituting this collection are the very first ones or among the first made by the respective inventors. Some are the only lamps of their type which have been made and they are all samples constructed early in the development of the period to which they belong. The collection comprises over 1000 lamps, each marking an important step, experimental or otherwise, in the development of the art. Mr. Hammer received the "Grand Prize" for his collection at the St. Louis Exposition of 1904.

The Committee feels that it can express its opinion as to the great historical value of this monumental collection in no better way than to quote from the letters and statements of a few of the ablest men of the scientific, engineering and commercial world, of whom over *200* have expressed themselves on the world, of whom over 200 have expressed themselves on the subject:

Prof. Elihu Thomson says of the collection: "It is perfectly unique, covers the whole period of development of the lamp, and it must be admitted by any one at all familiar with the circumstances that no similar collection could ever again be gotten together; in other words, your collection is impossible of duplication, or even approximate duplication. This statement cannot be made too strong."

Lieut. W. V. N. Powelson, Chairman of the Departmental Jury having supervision over the work of all the Electrical Group Juries, after the various members of the Jury had spoken in high appreciation of the collection, said: "In my opinion if the St. Louis Exposition were to give but a single Grand Prize, it should be awarded to William J. Hammer."

The following are extracts from some of the 200 letters which Mr. Hammer received, many of which are from leading authorities here and abroad. The originals were submitted to the Committee for examination. They are given here in the

order in which they happen to be and not necessarily in the order of their importance:

"I esteem it as a complete and unique showing of the progress of the Art from its first beginning to the present time and very valuable in that it cannot be duplicated. As such it would please me greatly if it could be secured by some institution where it would be safe from destruction and where it could be studied by every one so desiring." CHARLES BATCHELOR.

"I would like to see your collection remain in America as a priceless history of an art . . . You have the only collection of the kind in the world, as you have followed up your early collecting not only in this country, but in Europe." F. R. UPTON.

"This collection is worthy of being permanently preserved in a most careful and safe manner so that it may be accessible to electrical specialists and to the public generally."

PROF. FRANCIS B. CROCKER,
Columbia University.

"I regard your collection of historical incandescent lamps as unique in the Arts and as of the very greatest interest to all students of the history of this art. I consider that you have done great service to all such students by the pains you have taken to save the collection and exhibit it."

PROF. A. E. KENNELLY,
Harvard University.

"I consider this collection as of extreme value. Indeed it is unreplaceable and becoming of increased importance with every year of advance of electrical engineering. It is a history of the Art which cannot be reproduced any more."

DR. CHAS. P. STEINMETZ.

"There can be no dispute as to the extreme value of the collection; for it is, I believe, the only collection which shows the entire development of an art from very unpromising beginnings to a complete and world-wide success."

PROF. C. F. BRACKETT,
Princeton University.

"I feel confident in saying that it is the most complete and instructive collection illustrating the development in a great industry that I have ever seen." PROF. C. F. BURGESS,
University of Wisconsin.

"Such historical collections of apparatus as you have made are

of great interest to everybody, and are of increasing value as they are more nearly exhaustive as is the historical exhibit of incandescent lamps shown at St. Louis. The world has lost much valuable historic material in other arts for the lack of a like-minded man as yourself."

PROF. A. E. DOLBEAR,
Tufts College, Mass.

"Certainly few men have had the tenacity of purpose and persistent mastery of detail which has been necessary to the rounding out and development of this collection. It is a splendid example of what can be accomplished if in the present we map out for the future a plan of development and conscientiously carry it out. It is not often that the fulfillment of this principle is so forcibly presented in concrete form for our study."

W. E. GOLDSBOROUGH,
Chief Dept. Electricity, St. Louis Exposition, 1904.

"It is of course an exhibit that cannot be duplicated and one which reflects great credit on your patience and skill in getting it together. As a complete history of the development of an art of world-wide importance it undoubtedly stands alone, and as such is of great interest and value to both laymen and engineers."

FRANK J. SPRAGUE, Con. Elec. Eng.

"I believe it can be said without fear of contradiction that no other art has been so completely recorded as to its rise and progress by original physical exhibits. As it stands to-day it is a liberal education to study it. . . . I think a man who thus anticipates during the growth of a new art the needs of future history and of education, by patiently and systematically following up every clue in many lands, should be recompensed also for the foresight which has led him to do what others have overlooked as unimportant or given up as too laborious."

W. J. JENKS,
Sec'y Board of Patent Control.

"I remember well how eagerly you commenced your collection in the latter part of 1879 at Menlo Park, N. J., and know also how much time and money you have since spent in completing it. Twice I have met you in Europe over-running every country in quest of lamps, and with your connections here and in the States you have succeeded in getting together a complete set of lamps that show step by step the history of incandescent lighting. The importance and value of such a complete and only-existing set of incandescent lamps as that which you possess *cannot be appraised.*"

FRANCIS JEHL,
Electrical Engineer, Budapest-Hungary.

"I regard the collection as one of great value not only because it constitutes a remarkably complete history of the development of the incandescent lamp, but also because it is an object lesson which may be expected to influence workers, in other fields, to begin early and prosecute diligently the collection of apparatus embodying records of successive steps in the advancement of other arts."

L. B. Stillwell, Con. Elec. Eng.

"This collection is important and unique, representing as it does the entire history and progress of the art of incandescent electric lighting. Both the group and departmental electrical juries at the World's Fair took pleasure in recommending for the 'Grand Prize' your exhibit of your lamp collection and we appreciate that had it not been due to your personal effort, there would not be in existence to-day any collection adequately representing the history of the art of lighting by incandescent-electric lamps, nor could such a collection be possibly assembled."

Lieut. W. V. N. Powelson,
Chairman Dept. Jury, St. Louis Exposition.

"I have always regarded your collection of lamps and associated appliances as an exemplification and record incomparable in value in consequence of the evolution and wonderful growth of the art of electric illumination."

Thomas D. Lockwood, Elec. Eng.,
Am. Telephone and Telegraph Co.

"The collection of incandescent lamps which you have made illustrating the historical development of the incandescent lamp is a very valuable one and ought to be preserved in some public institution."

E. B. Rosa,
Bureau of Standards, Washington, D. C.

"I regard your collection of incandescent lamps as extremely interesting, and wish that they might find a permanent abode where they would be open to inspection by future generations."

F. P. Fish,
President Am. Telegraph and Telephone Co.

"Such a collection I should regard as being of considerable interest and much practical educational value. I trust that you will succeed in placing it where it will become a permanent exhibit."

George Westinghouse.

"In my judgment this collection of incandescent electric lamps ranks foremost among America's scientific historical collections, and as time goes on interest therein will increase and its importance to the engineering world and especially to electrical engineers of the

future will be infinitely greater and in fact invaluable. I most earnestly recommend that if possible this collection be permanently placed on exhibition where it will be safely conserved in one of our leading public institutions."

W. H. WHITESIDE,
President Allis-Chalmers Co.

"Permit me to say that your far-seeing intelligence in securing this collection, beginning at an early period that you did, merits the commendation of all interested in electrical science and electrical industry, and in this commendation I most heartily join."

CHARLES W. PRICE,
Editor Electrical Review.

"I shall rejoice to see you receive a fitting reward of your patience and industry in making this collection and in holding it together through so many years." T. C. MARTIN,
Editor Elec. World and Engineer.

"Nothing even approaching it in uniqueness and completeness is in existence in any of the allied branches of applied science. With no missing links in your collection you have made available for the engineering world a record of Electric Lamp development of which the value is inestimable." ALBERT SPIES,
Editor of Cassier's Magazine and Elec. Age.

"I well remember seeing these lamps at the St. Louis Exposition, and in common with all who saw it, was very greatly impressed with the perfection and completeness of the collection, which I am sure cannot be equalled by any similar one relating to a special industry in the world. I only wish that we in England could have an opportunity of access to such a valuable exhibit. As a member of the Electrical Jury at the St. Louis Exposition, I cannot do better than echo the opinion of the chairman of that jury as to the value of the collection."

DR. CHAS. V. DRYSDALE,
Northampton Institute, London, Eng.

"It goes without saying that this collection, which evidently represents the careful work of years, stands alone in technical history. To me the completeness and adequateness of the collection proves amply that it was with you entirely a labor of love. Such work is altogether too seldom seen in these days of fierce commercial competition. As such inventions may be considered among the greatest achievements of the race, it is vitally important that the historical documents illustrating the struggles and triumphs of our pioneers shall not be altogether lost."

LEE DEFOREST,
Vice-President DeForest Wireless Tel. Co.

"The collection not only signifies painstaking care and patience and labor, but an unselfish devotion to electrical science, which has prevented the ruthless destruction of these lighting landmarks which represent so much life blood and brain, and which if destroyed would in future time cause the greatest of regret. While not in that section of the Electrical Jury at the Louisiana Purchase Exposition, I certainly would have voted your collection the highest prize had it been in my power." PROF. J. C. KELSEY,

"I am certainly glad of this opportunity of once again confessing, as I have already confessed as a member of the Jury of the St. Louis Exposition, my great admiration of your historical collection, the perfection and importance of which cannot be overlooked by any student of technical history who is interested in the history and progress of the science and for this reason it is very desirable that the aforesaid collection should be placed in a position which shall easily be accessible to students."

PROF. GUIDO GRASSI, Turin, Italy.

"I consider that the person who has devoted himself to so laborious a task as was involved in creating this unique collection should be adequately recompensed by granting him the 'Grand Prize,' and for this reason I suggested in the course of our discussion on the subject of awards in the International Jury, the idea of granting to Mr. Hammer the 'Grand Prize' for his unique collection of incandescent lamps."

GASTON ROUX,
Con. Eng. and Director of Bureau of Control
of Elec. Installations, Paris, France.

In consideration of the great historical and educational value of this collection; of the years of unselfish labor and energy devoted to it; of its unreplaceable and monumental character, the Committee recommend the award of the Elliott Cresson Medal to Mr. William J. Hammer, of New York, for his "HISTORIC COLLECTION OF INCANDESCENT ELECTRIC LAMPS."

Adopted at the meeting of the Committee on Science and the Arts, held Wednesday, April 11th, 1906.

ATTEST: WM. H. WAHL, *Secretary.*

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SUPPLEMENTARY NOTE BY THE EDITOR.

In connection with this report there is published a plate *(See frontispiece)*, showing the appearance of this remarkable exhibit of lamps made by Mr. Hammer at the St. Louis Exposition.

Since the collection was exhibited at St. Louis, in 1904, he has supplemented it by samples of various lamps which have appeared since, particularly the Tantalum and Tungsten lamps.

It is Mr. Hammer's earnest wish that this collection shall be kept absolutely up-to-date as time passes, that it may always represent a complete "History of An Art," and to this desirable end he will always lend his enthusiastic co-operation. This has always been his wish and intention and in the years past he has been buoyed up in his laborious task by the hope that his work, if successfully carried out, would stimulate others to make similar collections forming priceless records of the inception, development and perfection of other arts, and perhaps ultimately result in an engineering museum in which engineers could deposit their models and inventions, where they would be properly safeguarded, where they would be of infinite interest to the world at large, where they would be of great service to the historian, where they would be a constant stimulation to the young engineer and to the inventor, and where they would be of enormous educational value to all engineers.

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## EARTHQUAKE RECORDS.

Prof. Harry Fielding Reid, of Johns Hopkins University, who is in charge of earthquake records for the United States Geological Survey, has sent out circular letters through which he expects to obtain important scientific data concerning the recent earthquake in San Francisco.

It may not be generally known that a few hundred dollars are devoted each year by the Survey to the collection of records concerning earthquakes. No very active seismological investigations have ever been made by this bureau, but a small allotment is granted Professor Reid, which enables him to correspond with observers all over the country and procure data recorded on seismographs at many different points. Reports of his investigations are published, from time to time, in the Weather Review, the official organ of the Weather Bureau.

It is interesting to note that Professor Reid was appointed by the State Department as delegate from the United States to the International Seismological Conference, held in Strasburg, Germany, from July 24 to 28, 1903. Delegates were present by invitation of the German Government from 19 countries, and an international association was then formed for co-operative investigation of earthquake phenomena. The constitution adopted provides for a general assembly to meet at least once in four years and a permanent commission, composed of one delegate from each nation, which will direct the work of the Association. A central bureau is

located at Strasburg in connection with the Imperial Seismological Station there, and reports are forwarded to its Director and are published from time to time.

The Association was joined by many countries, but the United States has not yet signified its intention of becoming a member. The permanent commission or executive committee of the Association was organized in Berlin last summer. Professor Reid was present at this meeting also. After his return he recommended, as he did after his return from the Strasburg conference, that the United States join the Association.

The Director of the Geological Survey has recommended in a letter to the Secretary of the Interior that the United States accept the invitation of the German Government to join the International Seismological Association, provided that Congress shall see fit to make the necessary appropriation. The total sum that Congress is called on to appropriate annually is $1,300, which includes $800, the fee that the United States would be required to contribute to the Association and $500 for the expenses of the delegate.

It is not likely that a delegate from the United States will ever have anything more important or more disastrous to report than the records of the earthquake which devastated the metropolis of the Pacific coast.

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## THE USES OF FLUORSPAR.

The highest grade of fluorspar, "American lump, No. 1," says Mr. Edmund Otis Hovey in a report of the United States Geological Survey on the production of fluorspar in 1905, is pure white or clear pale blue in color and does not contain more than 1 per cent. of silica. Such material is used in the manufacture of opalescent glass, in the making of enamels and "agate" ware, and in the production of hydrofluoric acid and other chemical compounds of fluorine. Both lump and ground mineral is shipped for these purposes.

The second grade of fluorspar, "American lump, No. 2," includes the colored varieties and is limited to a content of not more than 4 per cent. of silica. This is sold in lump or gravel form and is used in the manufacture of open-hearth steel, because it imparts great fluidity to the slag.

The third grade of fluorspar "gravel" includes all of the mineral that carries more than 4 per cent. of silica and all that is mixed with calcite. This material is used in foundry work on account of the clean character which it gives to iron castings. Through lack of knowledge of this property the demand for fluorspar for foundry work is much less than it should be.

Other grades known to the market are "crushed," "ground fine," and "ground extra fine."

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GERMANY'S production of coal in the first half of 1906 was 67,257,295 metric tons, against 56,630,591 tons in the corresponding period of 1905. The production of coke for the half year was 9,778,480 tons, as compared with 6,554,776 tons in the first half of 1905.

# A New Primary Battery for Large Currents.

*(Abstract of the remarks of* PROF. CARL HERING *at the stated meeting held October 18th, 1906.)*

At the monthly meeting of the Institute, held October 18th, Mr. Carl Hering, in his capacity as Professor of Electrical Engineering of the Franklin Institute, and at the request of the Secretary to bring before the Institute new developments of importance in the electrical field, made some remarks on a new and interesting form of primary battery for relatively large outputs, known as the Decker Primary Battery, which were accompanied by exhibits of the battery and its parts. Prof. Hering spoke substantially as follows:

Primary electric batteries for any but very small currents have had a bad reputation for many years. This is very unfortunate, as the primary battery in its proper place is an extremely useful and convenient generator of electricity. The fact that one company alone is said to be making and selling 100,000 per day, is conclusive proof that the primary battery in its proper sphere is an extremely useful article. The primary battery preceded the dynamo, but the latter has, during the past thirty years, made such enormous strides that its predecessor, the primary battery, was relegated to obscurity and its development was greatly neglected. A well known authority recently said that for the past fifty years no improvement had been made in primary batteries. It certainly cannot be denied that remarkably few improvements of any value have been made during that period.

The reasons why the primary battery has had such a bad reputation seem to be that so many batteries were brought out which were fakes and mere impositions on the public; and that so many inventors and promoters have neglected and tried to obscure the important question of the cost of the materials

which were consumed in every primary battery; the users were left to find this out for themselves; and thirdly, that primary batteries for relatively large currents have generally been constructed very badly from a mechanical point of view; they were extremely awkward to handle, were irrationally proportioned, were very difficult to keep clean, and the process of filling and emptying were very sloppy and tedious.

The primary battery in principle is a far more efficient generator of electricity than the steam or gas engine driven dynamo; that is, it is a very much more perfect converter of chemical energy into electrical energy, as it is not limited theoretically to a low efficiency by a certain thermo-dynamic law, as all heat engines are. The latter, as is well known, can not at best ever reach a moderately high efficiency. By "efficiency" is here meant the ability to convert as large a part as possible of the energy of the fuel into mechanical or electrical energy. On the other hand, however, this great advantage is more than counterbalanced by the fact that the fuel consumed in primary batteries is very much more expensive than that used in steam engines. The primary battery in its present form can not ever hope to compete with the steam engine and dynamo in the production of large quantities of electricity and no engineer would for a moment consider the replacing of the present engine and dynamo by primary batteries. But while this is true for the production of very large quantities of electrical energy, it is also true that for the production of smaller quantities the primary battery has decided advantages in economy of cost over the installation of an engine and dynamo plant.

It is even possible, although we may not live to see it, that at some future time a way may be found to get the energy out of coal directly in the form of electrical energy by means of some form of primary battery, thereby solving one of the two great problems at which so many engineers have been working. If this can not be done directly, there is open the possibility of an indirect method consisting of a primary battery in which the spent materials are again regenerated by means of coal, by a process which is not limited by that thermo-dynamic law. If one of these processes should at some future time be successful, the primary battery might have a fair chance of replacing the steam and gas engines.

The features of novelty of the Decker Primary Battery are the construction of the cell and its parts; chemically it is the usual bichromate cell. Some of these details are shown in the accompanying illustrations.

Fig. 1 shows a complete cell with the retaining cell removed; it has two porous cups P P and three graphite plates G G G. All these are secured together and to the bottom of the cell, so as to form mechanically a single piece. It also shows one of the corrugated graphite plates $G_1$ cut in two to show the corrugations. Also a porous cup $P_2$ cut in two to show the ribs inside. Also the terminal block B for the zinc plate $Z_1$. Fig. 2 shows the channels at the bottom of the cells and the holes

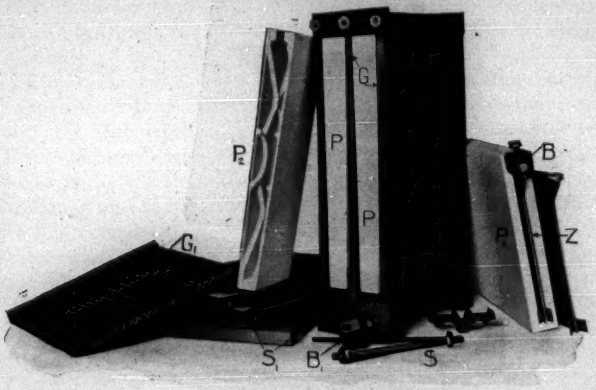


Fig. 1—Inside of one cell and the parts.

which connect with the porous cups. Fig. 3 shows a series of 16 cells with the two tanks of liquids below them, and the switch-board arrangements together with the pneumatic system of filling and emptying the cells. It also shows at the right hand bottom a very large cell having 10 zinc plates, which is shown here to-night.

The usual carbon plate is here made of graphite, molded first as carbon and then converted into graphite electrically. This makes it a better conductor and may perhaps increase the voltage slightly, as this cell on open circuit gives over 2.2 volts. The plate is corrugated and cross braced with diagonal ribs,

and it thus has a large surface and at the same time is strong. The upper part contains a brass rod or current collector imbedded in it nearly the whole width of the plate; this rod passes out through the side of the cell to the copper connectors and is therefore not exposed to the acid. It thus forms a low resistance connector for the graphite plate.

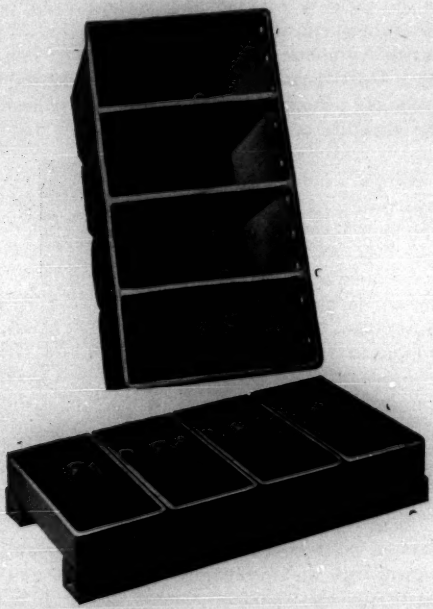

Fig. 2—System of channels in bottom of cells.

The zinc plates are made of rolled sheet zinc. They are amalgamated by a secret process which seems to be very effective, as I found in a test that there was no gassing and the consumption of the zinc was over 90% of the theoretical amount. These plates have a conical lug cast at the top, which fits into a conical hole in a zinc block secured permanently to the side of the cell by brass bolts leading to the copper connectors on the outside. The zinc

plates are therefore merely dropped into place and the connection is thereby made with the terminals without any screws or clamps, and as the only metal exposed to the acid is zinc, there is no local action there, which is often so destructive in other primary cells. The zincs are consumed very evenly and can therefore be used until they are quite thin. They are very easily replaced.

The zincs are in porous cups, which are of very ingenious construction. They are molded in two halves, with strengthening ribs on the inside surface. These halves are then secured together before baking. After baking, the outside surfaces are ground flat and to an even thickness. In this way, a very uniform, flat and strong cell is made, with thinner and more even walls than it would be possible to make by direct molding.

The retaining cell is made with channels in the bottom called the "irrigation system." One set of these communicates with the space around the graphite plates, while the other set communicates with the insides of the porous cups, through holes in their bottom edges. The two liquids are therefore introduced into their respective compartments from the bottom, through these channels. For a series of cells these channels are themselves connected to two main channels, thus enabling the whole series to be filled and emptied simultaneously from two tanks. The simplicity of this operation of filling and emptying is one of the chief advantageous features of the cell. The channels are made long and of small cross section, whereby they are given a high electrical resistance; the leakage of current or local action due to the cells being all in liquid connection with the same common tank, is thereby made negligibly small. By providing a large tank of solutions, the length of time during which the cell gives current with one charge of liquids may be made as long as desired. The liquids weigh only a fractional part of the whole, about 37% in one cell which I tested, and therefore by merely providing for two, three, etc., times the liquid, the discharge is made two, three or more times as long without increasing the weight very much. In this respect it differs radically from the storage battery.

The possible applications of such a battery are quite great. While of course it is not intended to replace the engine and dy-

namo, nor current or power from central stations where it is available, there are many other cases in which it is a question of either getting the current from a primary battery or not at all, as for portable purposes or to replace the storage battery. For instance, for a relatively small number of lights, or small motors, such as for fans, sewing machines, organs, piano players, dental engines, cauteries, etc. Or for train lighting. Or for launches, automobiles, etc.

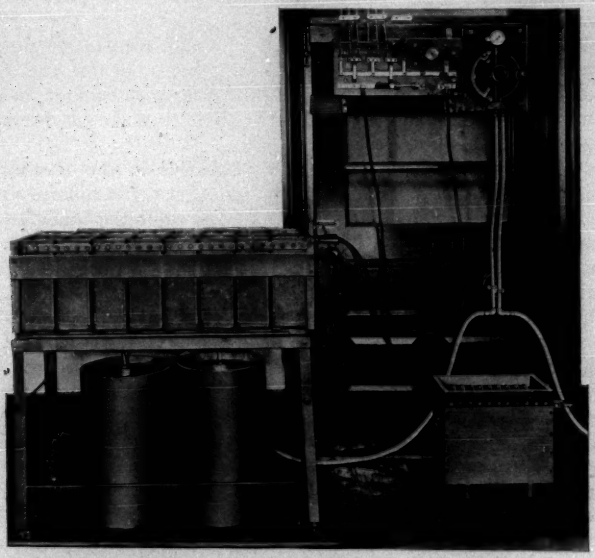

Fig 3—Sixteen cell battery with supply tank and controlling apparatus.

The cost was given by Prof. F. B. Crocker in a recent paper before the American Electrochemical Society as 35c. per H. P. hour for the zinc, acid and chromium salt. While this seems high, as compared with the cost of electrical energy from central stations, it should not be compared with it, as such a battery has its sphere of usefulness in places where current can not be obtained from central stations. The cost of the chemicals

in another form of primary battery, which is now used quite largely, he gives as $5.30 for a H. P. hour. If such a price is not prohibitive for that battery, the cost of the present one would not only not be prohibitive but a very great reduction. In comparing this cost with that of storage batteries, the depreciation of the latter must be taken into consideration as it is relatively very high. In Prof. Crocker's paper this cost for the storage battery is said to be greater than the cost of the electrical energy for charging them, at 10c. per K. W. hour. It is contemplated, moreover, to regenerate the spent liquids from this battery electrically. I can vouch for the fact that the chromium salt can be very easily and thoroughly re-oxidized with an electric current and the zinc can be recovered and the acid set free quite thoroughly. Should it be found that this can be done cheaply and economically, the field of the primary battery will at once be very greatly extended, and it will then have very great additional advantages over the storage battery.

A much fuller description of this battery may be found in a paper read by Prof. F. B. Crocker at the recent meeting of the American Electrochemical Society and reprinted in the Electrical World, October 13th, 1906, page 724.

I had occasion to make a test yesterday of the large cell on the table, having 10 zinc plates and shown in Fig. 3, on the floor to the right. Briefly, the results were as follows: It weighs about 100 lbs., was discharged at 100 amperes, and ran for nearly 6 hours, during which the mean useful voltage was 1.64. It therefore yielded $1\frac{1}{3}$ H. P. hours or nearly 1 K. W. hour. About $4\frac{1}{2}$ of these cells would yield a H. P. of useful energy; they evidently occupied much less space than a boiler, engine and dynamo giving this power. The capacity was nearly at the rate of 10 watt hours per pound of complete cell or about 80 pounds per H. P. hour. As it is now discharging before you through this thick iron wire, heating it to whiteness, it is yielding about 400 amperes and the voltmeter shows that even with this very large current, it is not being overworked and is by no means short circuited. Probably no one present has ever before seen a single cell of a primary battery generating such a large power.

Compared with a standard storage battery for about the same duty, I find that the storage battery weighs about three

times as much, occupies about twice as much floor space, and more than twice the volume for the same power. In capacity per pound, the primary battery was three times as good for a single charge of liquid and when used with a tank containing several charges, this figure would be still better. Another advantage of the primary over the secondary battery is that it is not injured by an abnormally rapid discharge, nor by too prolonged a discharge, both of which are likely to happen while in use and both of which seriously injure most storage batteries.

I have tested many primary batteries, but have never yet seen one which was so well constructed mechanically and electrically, nor which was so light and compact as this one for the amount of electrical energy generated.

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## ELECTRIC FOUNTAINS.

It is somewhat strange that only within a few years has the electric current been employed in connection with the illumination of moving water, thus creating what is known in this country as the electrical fountain. The first to attract general attention because of its picturesqueness was that designed by MacMonnies, forming one of the principal features of the Chicago Exposition in 1893. This superb electrical display attracted such attention that the electrical fountain for exhibition purposes became quite popular. Current generated at Niagara Falls was employed for a series of water illuminations at the Pan-American Exposition, and electrical fountains were seen also at the World's Fair at St. Louis.

Really the term electrical fountain is a misnomer, for the current is usually employed merely for illumination, and not in forcing up the water from the basin or other form in which the fountain has been designed. This work is generally performed by the ordinary steam or hydraulic pump, but where the location of the source of supply is not sufficiently elevated to furnish the requisite pressure. Several American fountains have been constructed, however, where the electric current is utilized for power as well as for producing the light effects.

One of the largest and most notable fountains of this class in the United States is located in Willow Grove Park, in the suburbs of Philadelphia. It is designed entirely for amusement purposes, and the various shapes assumed by the water columns at nightfall, reflected as they are in the rays of the varied lights, form a spectacle which attracts thousands. The water required for this fountain aggregates 50,000 gallons every twenty-four hours, and is supplied by one large and one small pump, the larger being actuated by two 50 horse-power motors working on a 500 volt current.—D. A. Willey, in *The Electrical Age* for June.

## Mining and Metallurgical Section.

*(Stated Meeting, held Thursday, October 4th, 1906.)*

# Recent Progress in Metallurgy.

By Alexander E. Outerbridge, Jr.,

Professor of Metallurgy, Franklin Institute.

In the annual address with which it has been my custom for some years past to open the autumn sessions of the Metallurgical Section of the Institute, I have endeavored to give a brief resume of the most notable achievements in metallurgy during the year, not only in practical applications of science to utilitarian purposes, but also to pay some attention to underlying theories and the ever changing views of physicists regarding the nature of ultimate particles of matter.

During the past year there have been few announcements of new discoveries in metallurgical processes, but there has been much discussion of new theories. We have been marking time, as it were, pausing to survey the field and to take more careful note of its topography. This does not mean that there has been no progress, but rather that the advance line which was at first erratic has been straightened and several blind leads have been abandoned.

In presenting new theories I have been careful to caution my hearers against accepting them unreservedly, for it seemed to me that theories which were so revolutionary as to upset all our preconceived notions of the stability of matter needed experimental demonstration of far more extended nature before they could safely be accepted as working hypotheses.

The subject is an abstruse one and in its present phase it appears to have little or no practical bearing, indeed it is fortunate that it is so, for the academic discussions now occupying the attention of many of the most noted philosophers of the

day, can be calmly studied without fear of disturbing any of our known metallurgical laws.

The classic investigations of Sir William Crookes on "Radiant Matter," published more than a quarter of century ago, paved the way for an entirely new conception of matter and seemed to prove one thing conclusively, viz: that particles of matter existed and were revealed in his high vacuum tubes very much smaller than the so-called atom, which was at that time thought to be indivisible. It is now believed that such particles (electrons) are so minute that it would require perhaps one thousand of them to make one atom of hydrogen. This may be accepted without the necessity of adopting the views of certain enthusiasts who have proclaimed that matter, as we know it, is of a transitory character; that transmutation of elements is no longer a myth, and that the actual process of evolution of one element into another has been observed in at least one instance, viz: that of the change of radium into helium as seen in the spectroscope.

We are told that radium is an evanescent element, that a process of disintegration is continually going on among its atoms and calculations have been made of its probable period of duration as radium. Speculations of this nature are exceedingly interesting and valuable in preparing the way for further study, but, as I have previously said, they must be received with caution, and within the past few months Lord Kelvin and other noted scientists have disputed the sweeping conclusions that have been drawn from such incomplete evidence.

In studying the subject we are brought face to face with the fact of our ignorance regarding the true nature of matter, and also to a realization of how little we know of the forces of nature. If the kinetic energy contained in a mass of radium is sufficient to raise its own weight of water to the boiling point every hour, there is evidence of a stupendous force, the nature and power of which are unknown to us, and these are perhaps the greatest modern mysteries calling for future solution.

Leaving now these purely theoretical considerations let us look at the progress that has been made in metallurgy from a practical standpoint.

During the past twelve months the production and consumption of all metals has been phenomenally large. This may ac-

count, in part at least, for the paucity of new discoveries and inventions announced within that time. It is an economic fact that lean years of production make fat years of invention and *vice versa* and the reason therefor is apparent. When we are straining every nerve to obtain the greatest output from our furnaces or to keep abreast of our orders we have no time for experimentation and we are less concerned about cost of production than during dull periods. At such times we cling tenaciously to routine methods.

The rise and fall in the production of pig iron has long been regarded as a sure indication of the condition of business in all allied lines of industry, and, if this be true, all records in the past must fade into insignificance as compared with those of the year ending June 30th last, for in that period of time the production of pig iron in the United States amounted to no less than 24,432,106 tons, or more than two million tons each month.

Ten years ago the production was 8,623,127 tons according to the statistics of the American Iron and Steel Association. If we hark back to the year of our Centennial Exhibition we find that the total production of pig iron was only 1,868,961 tons in 1876. Those who are interested in such matters will no doubt remember the astonishment that was caused when the statistics of the production of pig iron in the year 1898 were published, showing a total of 11,773,934 tons, or nearly one million tons a month. Since that time we have advanced by leaps and bounds as the following table for ten calendar years will show:

PRODUCTION OF PIG IRON IN THE UNITED STATES.

| | | | |
|---|---|---|---|
| 1896 | 8,623,127 | gross | tons |
| 1897 | 9,652,680 | " | " |
| 1898 | 11,773,934 | " | " |
| 1899 | 13,620,703 | " | " |
| 1900 | 13,789,242 | " | " |
| 1901 | 15,878,354 | " | " |
| 1902 | 17,821,307 | " | " |
| 1903 | 18,009,252 | " | " |
| 1904 | 16,497,033 | " | " |
| 1905 | 22,432,106 | " | " |

The production of pig iron in the State of Pennsylvania in 1905 was 10,579,127 gross tons or 1,956,000 tons more than the total production in the United States in the year 1896, and nearly 1,000,000 tons more than in 1897.

Hardly less astonishing is the phenomenal increase in the production of open-hearth steel ingots and castings in the past few years. As stated in the *Bulletin* of the American Iron and Steel Association, the production of open-hearth steel ingots and castings in the United States in 1905 amounted to 8,971,376 tons, as compared with 5,908,166 tons in 1904. 5,829,911 tons in 1903, and 5,687,729 tons in 1902. Of the total production in 1905 7,815,728 tons were made by the basic process and 1,155,648 tons by the acid process, as compared with 5,106,367 tons by the basic process and 801,799 tons by the acid process in 1904, 4,734,913 tons by the basic process and 1,094,998 tons by the acid process in 1903, and 4,496,533 tons by the basic process and 1,191,196 tons by the acid process in 1902.

The production of basic open-hearth steel from 1902 to 1905 shows an almost phenomenal growth. Comparing the production in these two years of basic ingots and basic castings we find that the ingot production in 1902 amounted to 4,384,129 tons, as compared with 7,609,569 tons in 1905, an increase of 3,225,440 tons, or over 73 per cent., while the steel casting production in 1902 amounted to 112,404 tons, as compared with 206,159 tons in 1905, an increase of 93,755 tons, or over 83 per cent. The growth of the basic open-hearth industry has not been confined to ingots alone during the last four years but has been shared by the steel casting industry.

The total valuation of all iron and steel industries, including the product of foundries and machine shops, architectural and ornamental iron work, etc., in the United States was, according to the U. S. Census Report of 1900, nearly $1,800,000,000, and as the output of pig iron has nearly doubled in the past six years, it is reasonable to suppose that the total valuation of all iron and steel industries has increased in similar ratio.

Five billion dollars a year is the estimated approximate value of the world's production of iron and steel annually and in this country the production and consumption have increased far more rapidly than elsewhere.

In 1876 the *per capita* consumption of pig iron in this coun-

try was under 120 pounds. In 1880 it was 205 pounds. In 1890 it had reached to nearly 283½ pounds.

It is stated that the consumption of iron per head in the United States in 1905 approximated 620 pounds as compared with about 68 pounds as the average consumption of the total production.

The remarkable increase in production of iron and steel in 1905 as compared with previous years has not been confined to the United States, but is world-wide. Our nearest neighbor, Canada, has taken the lead in relative increase of output, owing largely to the bounties paid by the Canadian Government on all iron and steel manufactured within the Dominion. The production of all kinds of pig iron in Canada in 1905 amounted to 468,003 gross tons as compared with 270,942 tons in 1904, an increase of 197,061 tons, or over 72 per cent.

The production of all kinds of steel ingots and castings in Canada in 1905 was much the largest in the history of the Dominion and exceeded by 254,665 tons that of 1904, an increase of over 171 per cent. The total output in 1905 was 403,449 gross tons as compared with 148,784 tons in 1904.

The production of pig iron in Great Britain in 1905 was the largest in the history of the United Kingdom, being 9,592,737 tons as compared with 8,562,658 tons in 1904, an increase of 1,030,079 tons, or over 12 per cent.

The total production of Bessemer steel ingots in 1905 amounted to 2,009,712 tons, against 1,781,533 tons in 1904, an increase of 228,179 tons or over 12 per cent.

The total production of open-hearth steel ingots in 1905 amounted to 3,879,748 tons, against 3,245,346 tons in 1904, an increase of 634,402 tons, or over 19 per cent.

The production of steel castings is never given in British statistics, nor is the production of crucible steel ingots. The production of crucible steel in Great Britain is estimated by the Secretary of the American Iron and Steel Association as amounting in recent years to about 100,000 tons annually.

In Germany and Luxemburg the production of pig iron in 1905 amounted to 10,987,623 metric tons, as compared with 10,103,941 tons in 1904.

The production of Bessemer and open-hearth steel ingots and

castings in 1905 amounted to 10,066,533 metric tons, as compared with 8,930,291 tons in 1904.

In France the production of pig iron in 1905 amounted to 3,076, 550 metric tons, against 2,974,042 tons in 1904.

The production of steel ingots and castings in 1905 is stated to have been 2,136,806 metric tons, as compared with 2,119,-359 tons in 1904.

Italy, Spain, Sweden and Russia all produce iron and steel, but accurate statistics for 1905 are not yet available.

In most of these countries there has been undoubtedly increased production as compared with previous years, although in Spain there was a slight decrease in production of pig iron in 1905 as compared with 1904, and an increase in production of Bessemer and open-hearth steel castings amounting to over 22 per cent.

These data have been obtained from the Annual Statistical Report of the American Iron and Steel Association for 1905.

### HIGH SPEED TOOL STEELS.

The use of ferro-alloys in the manufacture of "high speed" steel for cuttings tools has made great progress during the past year and has been extended in various directions with remarkable results. Large and costly milling cutters are now being made of this steel, as well as planer and lathe tools and drills. Improved methods of hardening and tempering this kind of steel have also been devised.

The advent of these tools has had already a far-reaching effect, not only on the time required for cutting metals, but also on the design and construction of machine tools. These must now be made much heavier and stiffer than formerly and the power required for driving them is correspondingly greater.

For example: In one instance where the output of a boring and turning machine was more than quadrupled by the use of high speed tools, it was found that the machine absorbed the entire driving power of the engine in the shop, whereas before the use of these tools this machine used about one-fourth of the whole power. In one of Mr. O. M. Becker's papers on "High Speed Steel in the Factory," printed in the *Engineering Magazine*, he says: "On steel speeds as high as 247 feet per minute (cut $\frac{1}{4}$ by $\frac{1}{8}$) have been attained for short times—and

this on 0.4 per cent. (carbon) steel. On such steel, however, 100 feet is all that can be desired for continuous performance, and 75 to 85 feet is in practice very satisfactory. In one instance 0.6 per cent. (carbon) steel is turned at a speed of 72 feet, feed 1-32, cut $\frac{3}{8}$, diameter of shaft 2 inches; but so far as reported nobody is able to do the same thing continuously—for the reason probably that in this case the job is done under exceptional conditions as to lathe, shape of tool, etc. Low carbon and machinery steel can be turned in large diameters and with light feed and cut as fast as 150 feet per minute, and sometimes even faster. In heavy cutting, say $\frac{3}{8}$ to $\frac{1}{2}$ inch depth by $\frac{1}{8}$ inch feed, 65 to 75 feet is all that can be recommended ordinarily."

In cutting of cast iron there are so many variables that it is impossible to arrive at a fair estimate of the value of high speed steel, the degree of hardness or softness of the metal, the size of the piece, the amount of adhering sand and its condition, viz.: whether it is loosely attached to the surface or is "burnt in," forming sometimes an abrasive surface similar to that of a grindstone, all have decided influence on the life of the tool.

I know of one instance in which certain cast iron bushings are being turned regularly day by day at a speed of 60 feet a minute which were formerly cut at about 30 feet a minute with the same feed and depth of cut. In this case, however, the iron in the casting is not quite the same as formerly, being now treated with a small quantity of a softening material in the ladle.

### FERRO-ALLOYS.

The use of ferro-alloys in the foundry is likewise extending. The simple method first described in the address given before the metallurgical section of the Institute a year ago for softening iron for castings to any desired degree has been continued, with exceedingly beneficial results.

The speed of turning pulleys has been largely increased and the time required to complete the machine work upon them has been reduced, and in other light castings as well. In addition to the material improvement in the strength of the metal by this treatment, there is a decided decrease in shrinkage, so

that some castings of irregular shape which are difficult to make without cracking in cooling owing to unequal strains are now made without this tendency by this process. Other advantages accruing from the addition of a very small amount of high-grade ferro-silicon (containing about 50 per cent. of silicon) have been observed. Among these may be mentioned the cleaning action upon the molten metal which the alloy effects by its deoxidizing influence. Singularly also it is found that commercially pure silicon does not produce these results, neither does the ordinary grade of ferro-silicon, containing about 20 per cent. of silicon.

Fig. 1 shows the fracture of two test bars cast from a ladle of untreated iron. The upper piece was cast in green sand

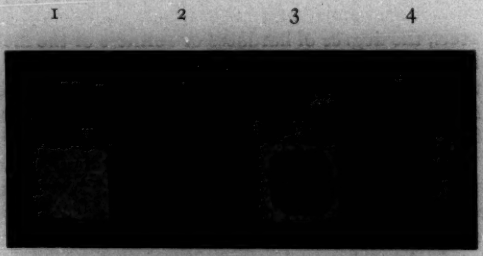


Fig 1 – Softening effects of ferro-silicon added to a ladle of molten metal.

1″×1″×15″ and was an ordinary transverse test bar. The lower piece was cast in a heavy iron cup in order to very rapidly cool the metal. The upper test piece is perfect'y grey and easy to drill. The lower one is perfectly white and can not be drilled with an ordinary steel drill.

Fig. 2 shows the fracture of two similar test bars poured from the same iron after addition of 0.3 per cent. of silicon in the form of high grade ferro-silicon (50% Si.) added in the ladle. Note the marked reduction in depth of chill in the sample cast in the iron cup.

Fig. 3 shows the fracture of two similar test pieces from the same iron after adding 0.5% silicon in the ladle. The "chill" is still further reduced.

Fig. 4 shows the fracture of two similar bars from the same

iron after adding 0.8% silicon in the same manner. The chill in the sample cast in the iron cup is almost entirely absent.

The samples cast in sand are all perfectly grey, but there is an appreciable difference in the fracture, the treated metal showing softer iron than the untreated sample.

The metal selected for this particular test was comparatively low in silicon, consequently having comparatively high chilling property, but this fact would never be suspected from an examination of the fracture of the test sample cast in sand. Very few practical founders are aware of the large variation in chilling property of their iron, sometimes of presumably similar grades, melted on different days, or even of the wide variations which may occur in different portions of one heat. The chill cup test here shown is an invaluable instructor in this matter, and without its aid the beneficial effects of adding high grade ferro-silicon to molten cast iron could not have been so readily detected and exhibited. These chill magnifiers have been used with great benefit in daily practice for more than twenty years. They are far more effective than the ordinary chill tests made in car wheel foundries. Such tests are only applicable for very high chilling iron, while the cup tests here described are only intended for use with comparatively low chilling irons.

In the case of pure silicon the specific gravity of the material is too low and its melting point too high to permit it to become incorporated with the molten iron in the ladle, in the other case the proportion of silicon is too low to permit a sufficient amount to be dissolved in the iron to produce a radical change in its quality without causing dull iron in the ladle.

There is no doubt that when the merits, simplicity, certainty of action and other advantages of this process of treating molten iron in the ladle are better known and appreciated it will come into very extensive use, for it enables the founder to modify the character of his iron to suit individual castings, a matter of considerable importance and value. This is accomplished without expense, for the cost of adding silicon to the iron in this manner is actually less than by the usual method of adding an equal amount of silicon to iron in the form of pig iron comparatively high in silicon added in the cupola. For example, pig iron containing 6 per cent. of silicon costs at the present time, let us say, $22.50 per ton, and we may estimate for

comparative purposes $3.75 per unit of silicon; ferro-silicon containing 50 per cent. silicon costs at the present time in powdered form $100 per ton, or $2 per unit of silicon on the same basis of calculation.

Furthermore, there is no loss of silicon when added in the ladle as there is when melted in the cupola, and this partly accounts for the fact that a given quantity of silicon, when added in the ladle, is much more effective as a softener than the same quantity charged into the cupola. Silicon added in the cupola always weakens the iron, while silicon added in the ladle always strengthens it.

### STEEL-HARDENING METALS.

The Mineral Resources of the United States for 1905, soon to be issued by the Department of the Interior, U. S. Geological Survey, will contain a special chapter on the production of Steel Hardening Metals, including Nickel and Cobalt, Chromium, Tungsten, Molybdenum, Vanadium, Titanium and Uranium, prepared by Mr. Joseph Hyde Pratt, from which the following data have been obtained:

During 1905 the total production of the steel hardening ores and concentrates in the United States amounted to 922 short tons, valued at $288,836. Of these tungsten was by far the most important as appears in the following table of production of Steel Hardening Metals in 1905:

| | Short tons. | Value. |
|---|---|---|
| Chromium | 25 | $375 |
| Nickel and Cobalt, Molybdenum, Titanium | 90 | 19,410 |
| Tungsten | 803 | 268,676 |
| Uranium and Vanadium | 4 | 375 |
| Total | 922 | $288,836 |

During 1905 there was no actual production of any metallic nickel or cobalt from native ores; at present practically all of the nickel used in the United States is obtained from matte imported from Canada and from ore imported from New Caledonia, the former furnishing by far the larger amount. The total quantity of nickel compounds of all kinds imported and

entered for consumption in the United States in 1905 was 31,072,206 pounds, valued at $1,962,131, and of cobalt oxide 70,048 pounds valued at $139,377.

The very general use of tungsten for alloying with steel, up to 15 per cent. and over, in the manufacture of high speed cutting tools has created a new demand for that metal and a corresponding increase, both in production and price. In 1900 the total production of tungsten concentrates in this country amounted to 46 short tons, valued at $240 a ton. In 1905 the production was 803 short tons, valued at $334.50 a ton. Tungsten ores are also imported free of duty and it is, therefore, impossible to obtain statistics for them. Ferro-tungsten-chromium alloys were imported to the value of $13,525 in 1905.

The production of titanium was entirely from Virginia in 1905 and was about 50 tons in amount.

A United States patent has recently been issued for the treatment of car-wheel iron in the ladle with powdered Rutile, the chief ore of titanium, for the purpose of increasing the hardness of the chilled tread. Without having had any experience with this process, I am unable to express an authoritative opinion regarding it, but on general principles, I should be inclined to doubt the efficiency of adding any ore to molten iron in a ladle.

The results of independent tests made by different investigators of the remarkable influence of small quantities of Vanadium in increasing the tensile strength of steel is likely to create a demand in the near future for that metal. The production of Vanadium and Uranium concentrates in 1905 amounted only to four tons, obtained from Colorado and Utah. There was, however, considerable ore mined which was not concentrated at all, but was stored waiting the erection of concentrating mills. The total tonnage of ore reported to the Geological Survey was 2,081 short tons.

A plant is in process of erection for the treatment of the vanadium sandstone found near Telluride, Colorado. A plant is projected at Castledale, Utah, in which to reduce the uranium ores of the vicinity by a nitric acid process. At Cedar, Colorado, a concentrating mill was recently built for treating the vanadium and uranium ores of that region. With the installation of these mills there should be a large increase in the

production of vanadium and uranium ores to supply the probable demand for alloying with steel.

## NICKEL-VANADIUM STEEL ALLOYS.

An interesting series of investigations on nickel and steel, vanadium and steel, and nickel together with vanadium in small quantity in steel have been published by M. Leon Guillet in the *Revue de Metallurgie*.

It was found that in the perlitic steels containing 0.2 per cent. carbon and from 2 to 12 per cent. nickel, the tensile strength and the elastic limit were both materially increased by the addition of small percentages of vanadium. A steel containing 0.2 per cent. carbon, 2 per cent. nickel and 0.7 per cent. vanadium showed a tensile strength of 91,000 pounds per square inch, an elastic limit of 70,000 pounds, and an elongation of 23.5 per cent. With 1 per cent. of vanadium, the ultimate tensile strength increased to 119,500 pounds, and the elastic limit to 91,000 pounds, the elongation falling slightly, viz: to 22 per cent. A nickel steel of 0.2 per cent. carbon and 12 per cent. nickel gave, with 0.7 per cent. vanadium, a tensile strength of over 200,000 pounds per square inch, and an elastic limit of 172,000 pounds, the elongation being 6 per cent., while with 1 per cent. vanadium the tensile strength rose to 220,000 pounds, and the limit of elasticity to 176,000 pounds, the elongation remaining unchanged. When the vanadium content is increased above 1 per cent. the tensile strength falls off, and the material begins to show evidence of brittleness. Similar effects are produced with steels of higher carbon, but in lesser degree.

The practical conclusions drawn are that the addition of vanadium is of value to steels containing from 2 to 12 per cent. of nickel, and in no case should more than 1 per cent. of vanadium be used. The result is to increase both the tensile strength and the elastic limit, especially if the steel is tempered by heating to about 850° C. and cooled in water at atmospheric temperature. These data have been obtained from a review of M. Guillet's paper in the April issue of the *Engineering Magazine*.

## BLAST FURNACE SLAG CEMENT.

In my address a year ago I called attention to the utilization of waste products in metallurgical works. One of the most recent developments in this direction is that of making cement of good quality from blast furnace slag, a waste product. Hitherto this material has not been found suitable for the manufacture of Portland cement owing, I believe, mainly to the presence of sulphur, but it is now stated that a process has been found for eliminating this objectionable element. When we realize that the output of cement in the United States in 1905 was over forty million barrels (an increase of 8,427,051 barrels over the product of the previous year) and that there are vast accumulations of slag at every blast furnace, the importance of the discovery of a process of utilization of this waste material as cement will be apparent. Referring to the subject in a recent issue *The Manufacturer* says:

"Changes of vast importance to the cement industry of the country are imminent, growing out of the experimentations, of the United States Steel Corporation, and it is stated that the corporation is on the verge of becoming the dictator in the cement industry, says a Pittsburg dispatch. It has worked out at the Chicago blast furnace plant a process for utilizing the waste product of the blast furnace, commonly known as slag, in the manufacture of fine grade cement. This matter has been experimented with for years and has always seemed feasible, as the chief portion of slag is the lime flux that comes from the large use of limestone in blast furnace practice. It is stated that a process has been found which fully fulfils all expectations, and it is the intention to erect a plant at once at the Carrie furnaces across from Homestead to be followed by plants at Braddock, Donora, Sharon, Duquesne and the other points where blast furnace slag has been accumulating as a nuisance for many years."

Officials of the United States Steel Corporation are forming a number of subsidiary concerns to the new Indiana Steel Company, at Gary, Ind., which will become potent factors in the general operation of that new industrial centre when all is completed. One of the most significant and interesting of these that has taken form during the last week is to be known as the

Universal Portland Cement Company. It has a capital of $1,000,000, and its plans, while only vaguely outlined thus far, are understood to contemplate the manufacture of a slag cement out of the furnace slag coming from the new blast furnaces to be built in the new town.

The Steel Corporation has been slow to give attention to the by-product of its furnaces, though an enormous consumer of cement itself. It has spent annually millions of dollars to dispose of its waste slag from blast furnaces, and is now having no little difficulty in getting rid of this material. In the mills and furnaces of the Illinois Steel Company there has been established a cement department which has been running with more or less success, but it has been hindered by the difficulty of eliminating sulphur from the slag. Its presence in the cement causes a disintegration after it has hardened unless set under and left under water.

Recently, it is said, the Steel Corporation has come into possession of processes that will eliminate sulphur during the process of making the cement. This will give the corporation a practical cement for all purposes with only the base cost of making it. The saving will be enormous, as there is no investment for cement deposits, nor for much machinery that is necessary for the manufacture of the ordinary rock cement. The raw material is a pure waste, and, passing through a process of extraordinary short duration of time, becomes a product of great commercial value.

The plant is understood to be one of a number that will eventually be put up. Some may be built in Pittsburg, where they can take over the slag from the scores of blast furnaces of the corporation in this vicinity.

Slag or puzzolan cement has been made to some extent for several years past at a few blast furnaces in this country, the product being chiefly utilized for certain parts of their own construction work. The total output in 1905 from nine works was 382,447 barrels. A characteristic analysis of puzzolan cement from the Ashland Iron Co., Kentucky, which is claimed to be the finest slag-cement plant in the country, is as follows:

| | |
|---|---|
| Silica | 35.72 |
| Iron oxide | .84 |
| Alumina | 9.72 |

| | |
|---|---|
| Lime | 45.42 |
| Magnesia | 2.85 |
| Sulphur | 1.42 |
| Loss on ignition | 3.66 |
| Undetermined | .37 |
| | 100.00 |

In reply to a recent inquiry for the latest information on this interesting and important subject, I have received the following statement from Mr. Robert W. Leslie, Vice-President of the American Society for Testing Materials, who is a large manufacturer of Portland cement:

"Broadly speaking, slag is utilized for the manufacture of cement in two ways:

"First: In the manufacture of Puzzolan or Slag Cement. This is produced by grinding slag mechanically with slaked lime to an impalpable powder. This, as you will notice, is a mechanical mixture, and when water is added to it, with sand, it will set and make an admirable mortar.

"Second: Portland Cement. In this case, which is the practice of the Illinois Steel Co., at their Geary plant and will be practiced at their new plants, slag is granulated and is ground to an impalpable powder with ordinary limestone (carbonate of lime) and this impalpable powder is fed into revolving kilns known as rotary kilns, where it is burned to clinker (incipient vitrifaction) by flames produced by the injection of pulverized coal into the kilns. This clinker is ground again to impalpable powder, and is the Portland cement of commerce.

"During the present year of 1906 the Illinois Steel Co., at their plant at Geary, will turn out from a million and a quarter to a million and a half barrels of Portland cement made under the latter process, and at their works at South Chicago, three or four hundred thousand barrels of puzzolan, made under the old process. There is no patent on either of these processes."

An interesting improvement in the pig iron industry, described in my address a year ago, to wit: the Gayley Dry-Air Blast Process, is worth noticing. The process has proved itself to be highly economical and will doubtless be largely introduced. During the year 1905 there was produced 276,000 tons of pig iron by this method, and several large plants are now in course of construction.

ALUMINO-THERMICS.

In my address a year ago I described the remarkable process discovered by Professor H. Goldschmidt, of Essen, for the instantaneous production of intense heat (approximating 3000° Centigrade) caused by the reaction between the metal aluminum in granular or powdered form and iron oxide, which has been applied successfully on a large scale in sundry metallurgical operations, notably, in welding of steel rails *in situ*, mending broken stern posts of vessels, etc., and in the production of pure metals and alloys. In order to obtain the most recent information regarding the progress during the year past the Secretary of the Institute, at my suggestion, wrote to the Goldschmidt Thermit Co. and received from the Vice-President the following reply:

"The progress made by the alumino-thermic process is naturally more of a commercial than a technical progress. The changes made in the manipulation have all been in pursuance of more simple methods, such as recommended themselves in actual practice in the field. For instance, for rail welding, a simplification consisted in cutting down the size of the mold boxes that surround the joint, to a point flush with the head of the rail. The former upper part of the molds, which contained the receptacle for the slag, has been replaced by a separate, so-called "slag box," made of cast iron, which sits tightly on the top of the mold boxes and can be easily removed after the pour, drawing the slag with it. In this manner it is possible, when welding under traffic, to allow cars to run over a welded joint without removing the mold, and to obtain greater speed in the welding operation.

"The shape of shoe for rail welding has also undergone modifications and it has been found that by checking the flow of metal under the base of the rail, a sensible improvement in the strength of the weld is obtained.

"More numerous operations on a large scale have provided welcome opportunities of observing the flow of thermit steel in large quantities. For such operations it is now made a rule to pre-heat the casting after the mold is in place, by driving air under forced draft through coke placed in a basket over the mold, the air passing in at the riser and out of the gate. This

system brings the part to be welded to at least dull red heat and assures the mold to be absolutely dry. The molds for such large operations must be made of 35 parts fire-clay and 65 parts sand. For such large operations the use of an addition of higher carbon iron, in the shape of rivets, is advisable, in the proportion of 20 to 25% of the amount of thermit brought to reaction.

"Among the more important operations of a large nature must be mentioned the welding of the keel bar of the 'Star of Russia,' December 28, 1905, in Oakland, Cal.; the welding of the stern post of the steamship 'Puritan' (1547 tons), April, 1906, in Chicago; the welding of the stern post of the steamship 'Alaska' (1288 tons), Buffalo, in May; the stern post of the tug boat 'Murrell' (311 tons), Boston, in July; the main shaft of the stern wheelers 'J. D. Peters' and 'Capt. Weber,' at Stockton, Cal., and of several large dredger bucket arms—one in particular, on a dredger bucket weighing 12 tons, with six cubic yards capacity.

"For welding wrought iron pipes, tubes and rods, a simplification of the process has been obtained by substituting cast iron for sheet iron molds. The dimensions of these molds have been tested out for all sections up to 4 inches in diameter.

"The process is now in regular practice by some thirty street railways for welding their rails, by a large number of railroads for repairing locomotive engine frames and by all the larger steel casting concerns, for repairing castings and increasing the temperature in their ladles and risers."

## PRODUCTION OF ALUMINUM.

The metal aluminum, once called "the metal of the future," is now entitled to a high place in the list of economic metals of to-day, the production having increased from a few pounds twenty-five years ago to about 5,000 tons in 1905. Owing to the discovery of the electrolytic method of refining the cost of the pure metal has declined from $8 to less than 40 cents a pound.

The great increase in production of this metal, which supersedes copper for many purposes, as in the manufacture of various alloys, also for conducting wires for powerful electric cur-

rents, etc., is all the more remarkable in view of the enormous increase in production of the latter metals.

Notwithstanding the fact that nearly all of the commercially pure metal aluminum is produced by one company in this country, and that there is no competition, the price has been reduced to a figure which enables it to supplant copper for many industrial uses; the high price of copper has, of course, widened this field materially. The electrolytical method of reducing the metal from bauxite—the only available ore—is too well known to need description here. Very recently an entirely novel method of producing aluminum has been devised, which does not depend upon bauxite and makes available vast deposits of clay, or alumina, which are not applicable to the electrolytic method. The following brief description of this new process is taken from a very interesting popular article on "High Temperatures and Modern Industry," in the October issue of *Harper's Monthly Magazine:*

"Thanks to Moissan and his methods nearly every metal has its carbide. For example, there is aluminum carbide, which Moissan prepared some years ago by heating in the electric furnace a mixture of kaolin and carbon. It constituted a body of beautiful yellow crystals which were apparently useless. Now, after all these years, comes the present discovery that this $Al_4 C_3$, so produced, on being heated with alumina (the oxide of aluminum) yields the pure metal and carbonic acid gas—a wholly new and elegant method of extracting aluminum, and one, obviously, of immense value when developed."

A practical method of plating aluminum on iron would be a very valuable discovery. During the past year two different methods have been published in technical papers, and being skeptical regarding their efficiency, I sent the formula of one to Dr. Joseph W. Richards, who is in charge of the Department of Metallurgy and Mineralogy at Lehigh University and a leading expert on aluminum; his reply to my inquiry is as follows: "The process of plating aluminium is new to me. It recalls the effort to plate Al. on the City Hall tower (Phila.), using Al. anodes and tin salts in the electrolyte. Of course aluminium went into the solution, but *only tin came out.* The same would occur with the electrolyte of $Na^2 S^2 O^3$, $Zn Cl^2$ and $NH^4 OH$. Zinc would come out as long as there was any

in the bath, while the aluminium would accumulate in the solution." The other process, devised by a Frenchman, M. Geroux, uses neutral copper acetate as the only metallic salt in the electrolyte. I have not been tempted to test it. In my address last year I called attention to the fraud that was perpetrated years ago on the City of Philadelphia, when large sums of money were paid ostensibly for plating the iron work of the great tower on the City Hall with aluminum. Irreparable damage by rusting of the exposed metal has resulted therefrom.

### PRODUCTION OF COPPER.

The increase in the production of copper in the United States in the past five years is quite as remarkable as the increase in production of iron, being in the present year at the rate of over one hundred thousand tons greater than the average for the previous five years.

In 1880 the production in the United States amounted to 25,000 tons, or about one-sixth of the world's output. In 1905 the production is reported at 413,070 tons, or more than one-half of the total output. The mines in the Lake Superior region contributed about one-fourth of the total production in this country.

The following table, giving figures for the year 1880 and 1905, is taken from a recent article on "The World's Copper Output," by John B. C. Kershaw, F. I. C., F. S. S., printed in *Cassier's Magazine*, September, 1906:

| Country | Production. | |
|---|---|---|
| | 1880. | 1905. |
| United States | 25,010 | 413,070 |
| Chili | 42,916 | 29,165 |
| Portugal and Spain | 36,313 | 44,810 |
| Germany | 10,800 | 22,160 |
| Australia | 9,700 | 36,560 |
| Cape of Good Hope | 5,038 | 7,325 |
| Japan | 3,900 | 35,910 |
| Russia | 3,300 | 8,700 |
| Norway | 2,426 | 6,295 |
| Peru | 600 | 8,625 |
| Mexico | 400 | 65,185 |
| Canada | 50 | 20,535 |
| Remaining countries | 13,506 | 10,470 |
| Totals | 153,959 | 708,810 |

The enormous increase in production of copper has been due partly to the increased demand for the metal since the advent of electric power for all purposes. Coincidentally with the increased production has come an increase in price of refined copper and decrease in cost of the process of refining. Mr. Kershaw says: "The average profits of the refining companies in recent years must, therefore, have amounted to over £15 per ton, and the aggregate profits of the producing industry in twenty-five years to the enormous total of £135,000,000 ($675,000,000) on a total production of 9,000,000 tons of copper.*

In 1880 the electrolytic method of refining was in its infancy, the total amount thus refined being 2,000 tons as compared with 350,000 tons in 1905.

In 1880 no refining by this method was recorded in the United States, while in 1905 the output of the electrolytically refined copper in the United States was 304,000 tons as compared with 46,000 tons in Europe.

The electrolytic process of refining copper is one of extreme beauty and simplicity. The process depends upon the passage of an electric current between two sheets of copper suspended in a tank containing copper sulphate in solution. As only the copper in the crude metal can act as a carrier of the current under the conditions obtaining in the vat, the impurities of the metal are left behind, and pure copper alone is deposited on the sheet of metal by which the current of electricity leaves the vat.

### GREAT INCREASE IN PRODUCTION OF GOLD.

The output of gold has quadrupled in the past twenty years, and stands, as regards its rate of development, above many other metallurgical industries. In a recent résumé of two papers by M. de Launay, an eminent French mining engineer, and professor at the Ecole Supérieure des Mines, published in the *Revue Générale des Sciences,* the *Engineering Magazine* says: "The enormous increase in the rate of production of gold is one of the remarkable industrial and economic phenomena of

*In October, 1904, copper was quoted in New York at 13c per pound, in October, 1905 at 17c and on October 15, 1906, at 22.62 per pound. Still higher prices are not unlikely in view of the extraordinary demand.

the present time. The curves representing the production of other metals have shown upward tendency, more or less marked, but the line showing the gold production of the world shows such a remarkable upward tendency that at times it almost approaches the vertical. When the curve is separated into its three components, representing respectively the three principal sources, the Transvaal, the United States and Australia, it is seen that there is a marked similarity between them, interrupted only by the break due to the war in Africa. The figures for the year 1905 given by M. de Launay, in francs, are: Transvaal, 524 millions; Australia, 432 millions; the United States, 436 millions; a total of 1,392 million francs, or about 278 million dollars. These three countries produce 72 per cent. of the world's total, which reaches 1,908 millions of francs. * * * It is largely because of the improved process of extraction that the production of gold has increased at the rates already given, since it is by the wholesale application of modern methods that the lowest grade deposits can be commercially worked. Thus, in a large and accessible mine it is assumed, on an average, that the material can be treated for about 12 francs per ton. Very often, however, the cost reaches double this figure, according to location and operative difficulties. In the great workings in Dakota, on the contrary, the cost has fallen as low as 2.10 francs per ton, and at the Alaska Treadwell mine to the minimum of 1.12 francs.

It is interesting to recall the fact that many years ago the assayers of the mint (Eckfeldt and DuBois) found that gold was uniformly distributed in very minute division in the bed of clay underlying the city of Philadelphia, and they made the astounding statement in a paper published in the Proceedings of the American Philosophical Society that there was more gold underlying the streets of the city than had been taken at that time from California and Australia combined. There was enough gold (according to their calculations) in each brick, if hammered into leaf, to make a sheet of gold two inches square and about one-three hundred thousandth of an inch thick. It was, of course, stated that the cost of extracting the gold would be far in excess of its value, but modern methods of refining low-grade ores had not been discovered at that time, and it may come to pass that the alluvial gold in the clay may

yet have a market value. This, however, is a mere speculation at present. Certain it is that the vast increase in production of gold in modern times is due to the economical methods of reclaiming the gold from lean ores that had no value whatever at the time this interesting paper was published.

### DECLINING PRODUCTION OF SILVER.

While the output of gold has doubled in the past ten years in this country, that of silver has shown a slightly declining tendency. In 1900 the output of our mines, according to the report of the U. S. Mint Bureau, was 57,647,000 troy ounces, having a coinage value of $74,553,495, while that of 1904 was 53,603,000 ounces, having coining value of $69,303,319.

The decline in production of silver has not been due to exhaustion of silver mines, but to the low price of silver. There are many silver mines now closed on this account which will again become active when the price of silver shall advance. The indications are that the bottom price for silver has been reached and that its value will gradually increase.* A very large proportion of the silver marketed in recent years has been a by-product from the refining of lead and copper, and I have been informed by a mining engineer of large experience that the actual cost of fine silver is, in some of these operations, less than ten cents an ounce.

The de-monetization of silver by most of the nations naturally helped the decline in value of this commodity; but, on the other hand, the low price has largely increased the consumption in the arts. Sterling silver is now replacing silver plated ware to a great extent, and the increased demand from manufacturers has created an enlarged market for silver. New methods of mining and refining have likewise reduced the cost of production, and the result of these conditions will, in all probability, be an increased annual output in the future.

The most notable advance in this direction is the great ex-

*This statement was in type when the latest sensational advance in price of silver occurred, when the U. S. Treasury Department purchased 150,000 ounces of silver for the Denver Mint at 70.13 cents per ounce, the highest price paid since the repeal of the Sherman Silver Purchasing Act in 1893. The price paid by the Government one year ago was 62.33 cents per ounce.

tension of the cyanide process to silver ores now taking place, especially in Mexico. Particulars relating thereto may be found in a paper by Prof. J. W. Richards in *Electrochemical and Metallurgical Industry*, September, 1906.

The world's product of silver was estimated at 173,000,000 ounces in 1901; the present annual production is believed to be about 3,000,000 ounces less than that, but, for reasons here given, it seems probable that silver will now join the procession of metals in increased production in the future, barring unforeseen commercial panics or other causes affecting the general prosperity of the nations.

## PRODUCTION OF OTHER METALS.

*Zinc.*—There was a fair increase in the production of spelter during the year 1905, the increase over 1904 being 17,147 short tons. The production has more than doubled since 1897, when it closely approximated 100,000 tons. The output in 1905 was 203,849 short tons, as against 186,702 tons in 1904. For the first time in the history of the zinc industry in the United States the consumption of spelter crossed the 200,000 ton mark. The total world production in 1905 was 727,141 short tons as against 693,022 tons in 1904.

*Antimony.*—The output in the United States in 1905 amounted to 3,240 short tons, the largest in three years, and only twice in the history of the trade was there a larger annual production. Notwithstanding the fact that there are good deposits of ore in several of the Western States, we mined no antimony in 1905. The entire market is supplied from antimony that is recovered as a by-product in refining base bullion which contains from 20 to 40 per cent. of antimony and by imports from foreign countries.

The chief use of antimony is for alloying with other metals, type metal containing from 17 to 20 per cent.; pewter a little over 7 per cent., and Brittania metal 10 per cent. of antimony. Aluminum-antimony alloys are also being made. Anti-friction metals for high-speed machinery contain antimony.

Some of the data regarding production of various metals have been obtained from advance chapters of Mineral Resources of the United States for the calendar year 1905, to be

issued by the Department of the Interior and were furnished by the Director of the U. S. Geological Survey.

*Tin.*—The advance chapter from Mineral Sources of the United States states that during the year 1905 there was no actual production of metallic tin in the United States, the only production being an insignificant quantity of ore from the placers of Buck Creek, Alaska. There was no output from the lode claims of the York region, Alaska; none from South Carolina, although 18 tons had been washed from the residual placers at Gaffner, in the northern part of the State in 1904; nor was any production reported from the Black Hills region of South Dakota and Wyoming. Prospecting was actively carried on in the Lost River Valley of the York region, where larger quantities of tin ore were shown to be present than had been known, and smaller veins were found at several points in the vicinity of the original discovery. No new occurrences of tin are known to have been found in the United States in 1905. The total world's production of tin in 1905 was a trifle over 100,000 short tons and was about the same as that of 1904. During 1905 the United States imported 44,188 short tons, about 43 per cent. of the total visible output. The price of tin at the opening of the year was 29.05 cents; since January 1st, 1906, the price has risen greatly, reaching 48½ cents on the New York market. One of the interesting late developments in Cornwall, England, is the proposed reopening of abandoned tin mines, owing to the present high price of tin. Cornwall has produced tin for more than 2000 years.

The following table shows the approximate tin output of the world during the year 1905:

| Country. | Short tons. | Per cent. |
|---|---|---|
| Australia | 5,028 | 4.88 |
| Banka | 11,155 | 10.81 |
| Billington | 2,715 | 2.63 |
| Bolivia | 13,646 | 13.23 |
| Cornwall | 5,040 | 4.88 |
| Malay States | 65,565 | 63.57 |
| Total | 103,149 | 100.00 |

The rise in price of tin has caused a search for substitutes in the manufactures. In an article on substitutes for tin by L.

Parry in *Mining Jour., Rwy. and Com. Gaz.*, London, June 2, 1906, various substitutes are given. Chief among these is the metal aluminum. Mr. Parry says: "The dimunition in the price of aluminum, the practically limitless supply of raw material, and the physical properties of the metal are facts which must at once appeal to the technical imagination, and point to this—the most abundant of the metallic elements—as a possible substitute for tin. At the same time it is not the only metal which has to be considered in this connection."

### CONCLUSION.

It has been my endeavor to show, as briefly as possible, the marvellous advance that has been made during the past few years in the production of metals all over the world, indicating wide-spread prosperity in the metallurgical world, also the lesser degree of progress recorded of new discoveries in metallurgy during the past twelve months.

It has, of course, been impossible to do more than to take a hasty glance at a few of the most striking developments. We have attained in this country during the past twelve months the highest pinnacle of activity and prosperity ever recorded; whether this shall prove to be the highest attainable point, the future will show.

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## PREMELTING ADDITIONS TO THE OPEN HEARTH BATH.

The Carnegie Steel Company has recently acquired two patents issued to William B. Hughes, formerly of Philadelphia and now with the Wellman-Seaver-Morgan Company, Cleveland, covering improvements in open hearth steel practice. The procedure consists in premelting, outside of the open hearth furnace, oxide of iron and mixing it with lime to form a highly oxidizing basic slag, the molten slag being added to the bath of molten iron on the hearth of the furnace. It is claimed that the improvement permits of working furnaces at their maximum capacity, renders unnecessary the use of very large furnaces, and saves the time heretofore required for heating the basic additions when charged cold on the hearth of the furnaces. The addition of the molten basic slag to the bath removes silicon and phosphorus from the iron without risk of injury to the hearth or lining, such as may result when the ore and lime are melted in the furnace. It is also stated that the molten slag acts more uniformly than if its constituents were charged into the furnace cold, and in the subsequent reaction and discharge of slag the loss of uncombined oxide, which is sometimes carried off mechanically, is prevented.—*Iron Age.*

## FREE ANALYSES AND ASSAYS OF MINERAL BY GOVERNMENT.

Among the numerous mistaken ideas that prevail regarding the functions of the Government one of the most general is that some department in Washington is prepared to make analyses or assays of anything in the shape of a mineral which may be submitted by any citizen of the country. Naturally, the Geological Survey is credited with this function and as a result not a day passes without the receipt of a dozen or more requests for such work. These requests are acknowledged with the statement that the Survey has neither the legal authority nor the available funds to make indiscriminate analyses or assays for private parties.

A small appropriation is made "for chemical and physical researches relating to the geology of the United States," but this is inadequate for the absolutely necessary chemical and physical work required by the geologists in connection with these investigations. Even if the appropriation were sufficient to provide ample facilities for making private analyses it could not be used for this purpose unless such analyses were directly contributory to the solution of some geologic problem. Fortunately, a large proportion of the specimens submitted can readily be determined by means of simple tests and careful visual examination. Such a determination is always made wherever possible, and the person who submits the mineral is given all the information available regarding it. In most cases this is quite as satisfactory as the result of an elaborate and expensive analysis would be. A large proportion of the specimens submitted are absolutely worthless, some have a commercial value only when occurring in large masses and convenient to transportation, while a few afford clues to new occurrences of rare and interesting minerals, which are of great value in connection with the regular work of the Survey.

It is not expected or desired that the practice of sending in minerals for determination should be discontinued, but it is best that the public should not rest under a misapprehension as to what can be done with them.

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## DANGER OF HIGH CHIMNEYS IN EARTHQUAKE REGIONS.

The experiences of the recent earthquakes have forcibly emphasized the marked advantages of the short steel stack, which is all that is essential with a mechanical draft installation. High brick chimneys have proved to be sources of danger. Their wrecking on all sorts of buildings in the stricken region was no inconsiderable factor in the general destruction. Most of the power stations around San Francisco came through in pretty fair shape, save for the stacks, thanks to the fact that most of the plants were fairly well built and did not carry their weights too high. After this experience tall chimneys may be counted on as pretty certain to go in a severe earthquake. On the other hand, there is much to be said for short stacks and forced or induced draft. This construction, which has entered into recent equipment in Japan, suggests still another of the advantages of this modern system of draft production.—*Iron Age.*

## Section of Physics and Chemistry.

*(Stated Meeting, held Thursday, May 10th, 1906.)*

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# Notes On Some Recently Devised Tests.

By Henry Leffmann.

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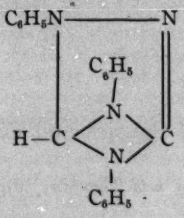
*Precipitant for Nitric Acid.*—The fact that, until very recently, no normal nitrate sparingly soluble in water was known, has prevented the determination of nitrogen in this form by direct methods. Although some of the indirect methods have been fairly convenient and satisfactory, it is always desirable to have a direct process.

M. Busch (*Ber.*, 1905, 861,) found that a complex derivative of pyrrol forms a nitrate which is so slightly soluble in cold water that it can be satisfactorily used as a precipitant for nitric acid and nitrates. The substance has been termed "nitron" by Busch, to avoid the long systematic title (diphenyl-endanilo-dihydrotriazol.) It is a bright-yellow, soft, crystalline powder, sparingly soluble in water, but dissolving with ease in many dilute acids. The most convenient form is a solution of 1 gram in 100 c.c. of 5% acetic acid. This solution is brownish and keeps pretty well, but it is inadvisable to make up a large amount at once.

With this solution a white flocculent precipitate forms at once when added to a liquid containing notable amounts of nitrates or nitric acid; with small amounts some time is required and the solution should be cooled to 0° C. The precipi-

tate is a normal mononitrate. The structural formula of the reagent is



The empirical formula is $C_{20}H_{16}N_4$; the nitrate is $C_{20}H_{16}N_4 HNO_3$. The molecular weight of the nitrate is 375.

The calculations are made as follows:

Weight of nitron nitrate + 0.167 = $HNO_3$
" " " " + 0.269 = $KNO_3$
" " " " + 0.037 = N as $NO_3$

The process has been specially studied by A. Gutbier (*Zeit. Anal. Chem.*, 1905, No. 13, p. 494,) who gives the following details, substantially those given by Busch:

"Dissolve 0.1 to 0.15 gm. of potassium nitrate, or a corresponding amount of the other material to be tested, in 80 c.c. of water in a beaker covered with a watch glass, add 12 to 15 drops of dilute sulphuric acid, and bring to boiling temperature; remove the flame and add to the hot solution 12 to 15 c.c. of the above-mentioned acetic acid solution of nitron in acetic acid; stir the mixture and allow to stand for ½ to ¾ hour, during which time the nitron nitrate will crystallize out. When the solution has attained room temperature place the beaker in ice water and after 1 to 1½ hours collect the precipitate on a weighed Neubauer crucible by decantation of the original solution, using gentle suction, wash with 10 to 12 c.c. of water at 0° C., dry, and weigh."

Chlorids, carbonates and sulphates do not interfere. The interferences are principally substances that are not likely to occur with nitrates, or can easily be detected and removed, such as bromids, iodids, chlorates, perchlorates, ferrocyanids, ferricyanids and sulfo-cyanates.

*Determination of Sulphates.*—A volumetric method of determination of sulphates is desirable. Several have been pro-

posed, but they have not had much vogue. The latest suggestion promises to be of much use, the test analyses being satisfactory. It depends on the fact that benzidin sulphate, $(C_6H_4)_2(NH_2)_2H_2SO_4$, is insoluble in water and dilute acids, and that benzidin hydrochlorid $(C_6H_4)_2(NH_2)_2(HCl)_2$ can be titrated as if it was hydrochloric acid, by sodium hydroxid or barium hydroxid, using phenolphthalein as an indicator. The precipitating solution is prepared by dissolving about 40 grams of benzidin hydrochlorid in 500 c.c. of water with a few c.c. of hydrochloric acid, and making the solution up to 1000 c.c. It keeps for some time, if kept in the dark. The solution is titrated with sodium hydroxid or barium hyroxid and the amount required for neutralization noted.

A convenient amount of the solution to be analyzed is introduced into a 250 c.c. flask, rendered exactly neutral, made up to about 150 c.c., and heated in the water-bath. Benzidin hydrochlorid solution is added in excess, the amount added being exactly noted. The solution is cooled, filled to the mark, shaken and filtered. An aliquot part is titrated. The difference between the alkali required for this and that required for the same proportion of the benzidin hydrochlorid before precipitation is the equivalent of sulphuric acid precipitated. The following equation shows the type of the reaction:

$$(C_6H_4)_2(NH_2)_2(HCl)_2+K_2So_4=(C_6H_4)_2(NH_2)_2H_2So4+2KCl$$

257 of benzidin hydrochlorid precipitates 98 of sulphuric acid or the equivalent of any sulphate.

The precipitated benzidin sulphate is white and flocculent.

*Detection of Ammonium Compounds.*—Trillat and Turchet (*Bull. Soc. Chem., Paris*, 1905, No. 6, p. 304,) describes a simple test which they claim to be more delicate than Nessler's reagent. A few drops of a 10% solution of potassium iodid are added to the solution to be tested (which should be neutral), and then drop by drop with shaking, a solution of sodium hypochlorite. The ordinary commercial solution will answer. In the presence of even very small amounts of ammonium compounds a brownish precipitate of the so-called nitrogen iodid is formed. The substance is probably largely diiodamin $NHI_2$. The reagents, especially the potassium iodid, should be added in small amount, otherwise free iodin may be precipitated. T. & T. find that free iodin may be distinguished

from the nitrogen compound by agitation with chloroform which dissolves the former at once, but acts only slowly on the latter. They find, however, that chloroform slowly decomposes the nitrogen compound.

The convenience of the test and the ease with which the reagents can be obtained will give it value in clinical and sanitary chemistry.

*Precipitant for Potassium.*—Alvarez (C.r. 140 (1905) 1186) finds that the photographic developer, commonly called "eikonogen" (a sodium naphthol sulphonate) forms a sparingly soluble potassium salt. A five per cent. solution of the eikonogen in water is used as a reagent. This solution must be freshly made as it decomposes in a few hours. The precipitate is in colorless plates and is also liable to decomposition.

*Test for Cane Sugar in Milk Sugar.*—I have found that the reaction with sesame oil and hydrochloric acid is a satisfactory test for sucrose in lactose, being better than carbonization with sulphuric acid. The test is applied by mixing about 1 c.c. each of sesame oil and strong hydrochloric acid, adding about 0.5 gram of the same to be tested, shaking actively for a few moments and then allowing the liquid to stand for thirty minutes. As little as one per cent. of sucrose can be detected, but for such quantity, it may be necessary to allow the liquid to stand for a longer time. Sucrose can be easily detected in milk-products, and the test will be applicable to the detection of the comparatively new "cream-thickener" consisting of calcium oxid and sucrose. I am studying the applicability of the test to other carbohydrate mixtures.

## PROPOSED SUBWAY AT PITTSBURGH.

A number of capitalists of Pittsburgh, among whom is F. T. F. Lovejoy, formerly Secretary of the Carnegie Steel Company, have organized the Pittsburgh Subway Company and have asked the councils of that city for a franchise to build a complete system of subway and surface traction lines from the downtown section in Pittsburgh through the East End and Wilkinsburg. The estimated cost of the subway and traction lines is given as $30,000,000, and the projectors promise to push work as fast as possible. At present traffic through the Pittsburgh downtown districts to the East End is very much congested and is steadily growing worse, owing to the rapidity with which the outlying districts near Pittsburgh are building up. —*Iron Age.*

*(Stated Meeting, held Thursday, October 11th, 1906.)*

## Low Pressures: The Death of Matter.

[Translated by Chief Engineer B. F. ISHERWOOD, United States Navy, from the 5th Chapter of "L'Air Liquide," by GEORGES CLAUDE, former pupil of "The School of Physics and Chemistry," Paris.]

If Industrial Science should be able to congratulate itself on the progress now being made by Liquefied Air, so that there could be said of it with satisfaction that it will furnish in the future a lever as potent as was steam or electricity in the last century, then there could be predicted that astonishing surprises will be produced by Low Temperatures in the domain of Pure Science.

And were it not temerity to attack such high subjects in so modest a work as this, the attempt could be made to show from all the apparently disconnected facts now to be passed in review, how great has been the shaking which the seductive ideas accepted up to the present time by modern physicists have received in their firmest seats.

The notion of *cold*, created and put into the world for the purpose of explaining the opposed sensations of our organism, has been entirely superfluous in science for a long period, having been included in the notion of *heat*. A body *colder* than another is a *less hot* body. A body that cools is a body which loses heat. Pause a little on this last image. To say that a body loses heat is to imagine that it holds within itself a certain quantity of caloric, a quantity, evidently, that could not be unlimited. If, then, this body be placed under proper conditions, there could be extracted from it all the caloric it contained, and it would be brought to the extreme limit of cold—to the lowest temperature that could possibly be realized—which temperature is, for that reason, qualified as the *absolute zero*.

This conception was, at first sight, purely intuitive and philo-

sophic. It came in a direct line from the ideas of Stahl concerning phlogiston; and was the first theoretical essay that gave to modern science its first successes.

Certainly, there was not yet any question of appreciating the depth to which it was necessary to descend on the scale of temperatures in order to reach the ultimate limit of the absolute zero; but, already thinkers could perceive in this intrinsic heat of bodies the cause which animated the world of matter.

In a brilliant article in the *Revue de Paris,* of April 1st, 1903, Mr. L. Houllevigue has said: "They saw matter formed of "molecules or aggregated molecules isolated from each other "and pursuing each other in incessant movement like the par- "ticles of dust vibrating in the sun-beam, and from this eddy- "ing mass they saw escaping waves that propagated themselves "in space by means of an infinitely rare medium which was to "the lightest of known bodies, hydrogen, what the density of "hydrogen was to the density of the heaviest metals. Gases, "especially, appeared as microscopic projectiles darting in "every direction, and continually bombarding, without loss of "force, the sides of the vessel that contained them, only to re- "bound again and recommence their eternal movement. The "heat contained in the gases took from similar impacts a "more precise significance, it showed the present energy of all "these moving corpuscules; if the gas be cooled, the velocity of "the projectiles diminish, their trajectories flatten, then, all the "corpuscules collapse, but still retain eddying movements; this "is liquefaction. Then, in measure as more and more energy "is taken out of them, the vibrating molecules make less and "less extended movements, and the liquid contracts in cooling. "Very soon the increasing nearness of the molecules to each "other enables them to make among themselves new inter- "actions, their relative positions become nearly invariable, and "the liquid solidifies; but the resulting solid is still animated "with life-like shiverings; it could still be cooled down to the "point at which its molecules would repose, inert, one upon the "other; and then the matter would be dead."

Little by little, precise experiments have given to these superb conceptions the physical bases they needed, and the beginning of certainty to what previously were merely presumptions.

Gay-Lussac supplied in evidence a fact of extreme importance.

Under the action of heat all gases dilate and contract in the same manner; whatever may be their nature, they contract when they cool; they contract by the two hundred and seventy-third of their volume at 0 degrees Centigrade for each lowering of one degree Centigrade in their temperature; if, then, the temperature could be lowered to 273° below 0°, the volume of the gases would become nul. Or if, conformably to the ideas that have been previously expressed, if the size of the intermolecular spaces be connected with the quantity of heat in the body, then, if, in the case of gases, these spaces become nul at 273°, the gases would contain no heat, and, consequently, they would be at the absolute zero. The notion then becomes precise.

Nevertheless, it might be rash to draw, without further precautions, so general a deduction from one particular set of facts. But, on all sides, and in quite different fields of investigation, very precise facts do appear which add to the foregoing deductions the important support of their evidence.

One of the most remarkable can here be cited, obtained by the genius of Ampère previous to the announcement of the fact in question.

Pressed by the necessity of combining in the same theory the inseparable phenomena of electricity and of magnetism, the illustrious scientist was led to consider magnetism as due to the circulation of currents of electricity around each molecule of the magnetized body. One difficulty, however, embarassed him, namely, how to reconcile the expenditure of inherent energy in the circulation of the electrical currents as they are revealed to us, with the maintenance, indefinitely and without expenditure of energy, of the magnetism of the magnets? The adverse argument assuredly required refutation, and an admirable hypothesis enabled it to be made, which later discovered facts confirm in the most remarkable manner. According to this hypothesis, the conducting molecules do not oppose any resistance to the propagation of the current; electrical resistance only appears during the passage of the current across the intermolecular spaces. Now the elementary currents preserving the magnetism of each magnetized molecule

not having to pass through any intermolecular space, can persist indefinitely without expenditure of energy. In this manner is reconciled with the thesis of the identity of magnetism and of electricity, the disconcerting fact of the permanence of the magnets.

But an hypothesis can only remain in science by the verification of the different consequences predicted by it. Now, from Ampère's hypothesis can be deduced that the electrical resistance of good conducting bodies ought to diminish with their temperature, since when they cool they lessen their intermolecular spaces which the current has to cross. This consequence is perfectly verified by experiment: not only does the resistance of the pure metals diminish when their temperature lowers, but this diminution takes place with such regularity that by prolonging the curves of resistance beyond the experimental limits, the temperature can be found to which it is necessary to descend in order that all resistance completely disappear, which is to say, in order that, according to Ampère, the molecules come into absolute contact with each other.

Now—coincidence very remarkable—the physicists, who, at the suggestion of Maxwell, proceeded to make, for the first time, this extrapolation, found in this manner precisely the limit 273° Centigrade which the gaseous theory assigns for the absolute zero! This was at once, could it be implicitly accepted, a striking justification of the views of Ampère, a confirmation of the theory which assigns to magnetism and to electricity a community of origin, and the definitive establishment of the ideas of the physicists regarding the absolute zero.

Besides, each limit surpassed by the succeeding one in the production of low temperatures, has been the object of verifications that rendered more and more complete the confidence of scientists. At the temperature of liquefied air, about 85° Centigrade above the absolute zero, the diminution in the resistance of pure copper, also the contractions of hydrogen and of helium, furnished precisely the results calculated in advance from the theories of Gay-Lussac and of Ampère: the cohesion of the metals was considerably augmented conformably to the *desiderata* of modern physics, and the fatal stroke was given to the partisans of that old and poetical cosmogonical theory of Laplace, according to which the interattraction of matter re-

laxed at low temperatures in order to permit dead stars to fall to dust and contribute their ashes to the formation of new worlds.

Finally, the most violent reactions at atmospheric temperatures calm down in a progressive cooling to such an extent that at the temperature of liquid air they preserve only a pale reflex of their primitive vivacity, thus putting in striking relief the entrance of matter into that lethargy which is the commencement of its definitive death.

Notwithstanding all this, and the investigations of Dewar, and the magnificent work of the "Royal Institution," a considerable interval is still left in the march towards the absolute zero.

In 1899, after five years of researches and of persevering effort, liquid hydrogen, the substance, according to certain physicists, of which the enormous globe of Saturn is composed, is, for the first time, manipulated by human hands. By means of it, only 21° Centigrade separates us from the absolute zero; that is to say, one-fourth of the interval which still remained with liquid air. Palpitating moment! At this temperature can a decisive experiment be made to establish definitively our science on the most essential foundation? Bitter disillusion! Plunged into the bath of liquid hydrogen protected by triple spaces of vacuum from being heated externally, the experimental copper-wire shows only a reduction in its resistance to the one hundred and fifth of its initial value, an enormous reduction without doubt, but insufficient to enable the curve to touch at the absolute zero, the axis of the abscissas.

This poignant disappointment seems, for the rest, to be only a warning.

While the scientists expected to find at the temperature of liquid hydrogen a complete cessation of all reaction, Dewar and Moissan found there a violent combination of fluorine and hydrogen: while the matter ought to be despoiled of all energy in its progress towards the absolute zero, it appears, on the contrary, capable of acquiring, *en route*, new energies, as witness the phenomena of phosphorescence and of fluorescence, which, very rare at ordinary atmospheric temperature, are the general rule at the temperature of liquid hydrogen.

And more surprising still; not only does the matter not ap-

pear moribund, but life itself seems capable of resisting this extreme cold; witness microbes vigorous after weeks of immersion in liquid hydrogen; witness seeds of cereals which, under the same circumstances, lose nothing of their germinative faculties; tending thus to furnish reason to the defenders of the very original thesis of the community of the origins of life in the universe, since the vital germs would have been able to be transmitted from one planet to another without being destroyed by the enormous cold of the interplanetary spaces.

Are we then definitively to have done with our old theories, so simple and so seductive, and from which so many experimental and philosophical deductions seemed to constitute a harmonious whole? Is it necessary that we resign ourselves to the belief that nothing is simple in nature?

Certainly, at this moment the motives are not lacking to incite to that deceptive belief the scientists whose convictions have thus been weakened. With radium, have they not on other primordial points collided with the inexplicable? With regard to this science of low temperatures itself, have they not seen the complexity, almost the confusion, produced by introducing it into a question which from the origin of chemistry seemed so simple as that of the constitution of the atmosphere?

The atmosphere, in fact, is no longer the invariable mixture of nitrogen and oxygen with which we have been so familiar. After the first shock given to this belief by the discovery of Argon, surprises multiplied in a singular manner when the liquefaction of air and of hydrogen allowed the undertaking of their fractional distillation, the result of which is that ten new elements have been discovered.

Nevertheless, who can say whether we do not alarm ourselves too soon, and whether all this troublesome complexity is not more apparent than real? If radium conceals its mystery too jealously, perhaps we can hope on other points a more simple explanation. If, as many eminent minds believe, the unity of matter will at some future time be demonstrated, it is not the fact of having found in the atmosphere somethings to lengthen the list of our simple bodies that will be a difficulty, since they will act only as added terms of a more or less condensation of the prototype of all matter, of the *pantogen* of

Hinrich and of Schutzenberger, which is, perhaps, after all, only the *ether* of the physicists.

Still better is the chance of finding in the terrestrial atmosphere the *nebulum* that sends its radiations from the distant mass of stars which form the Milky Way; coronium or the gas of the solar crown; *helium*, of which the sun and some stars retain up to the present time a monopoly; the fact of adding all these new proofs to all the previous proofs of parentage established between the earth and the stars by the existence in the latter of iron, of sodium, of hydrogen, and of many other lodgers in our globe; these facts will so much the sooner form a new road towards the demonstration of the original simplicity of things, since they support the great idea of the unity of the constitution of the universe, reinforced, as has been shown, by the possibility of attributing life to a single origin. Finally, as appreciable compensation for that complexity, a little light has been seen at last on the irritating mystery of the boreal auroras, which scientists have despaired of every solving, but whose radiation-enigmas have been identified with the specter of some of the new atmospheric gases.

And now, returning for the last time to low temperatures, the question can be asked, and in an analogous spirit, if there has not been, at least, some exaggeration attached, as appears to have been the case, to the unhoped-for results found for the temperature of liquid hydrogen, to the point of putting in doubt, at a single blow, all our old beliefs?

We very well know now, thanks to the indications of the theory confirmed by the investigations of Dewar, that in measure as the absolute zero is approached, the difficulties of ascertaining the temperature increase with enormous rapidity. In reality, the thermometric scale, graduated according to conditions of a certain order, ought not to be regarded as constituted from one end to the other of degrees of identical importance. It is by *ratios* between the absolute temperatures, much more than by *differences* between them, that the importance of the successive points is measured, so that the degrees as they approach the bottom of the scale acquire, consequently, an extreme importance.

Thus, the difficulties of descending from the ordinary atmospheric temperatures to the = 190° Centigrade of liquid air, is,

so to speak, nothing comparatively with the difficulties of reached the $-252°$ Centigrade of liquid hydrogen, because these $=252°$ represent an absolute temperature of $273-252=21°$ Centigrade, *four times less* than the 83° Centrgrade absolute of the liquid air. It was thus, too, that Dewar, by means of ebullition in the vacuum of liquid hydrogen, and by its solidification, was easily enabled to reach $=258°$ or 15° Centigrade absolute, but he has not been able, notwithstanding that source of refrigeration, to attain in a similar manner the liquefaction of helium though only separated by 8° Centigrade, because, in reality, the 7° Centigrade absolute necessary to be obtained, represents a temperature *twice lower* at least than that of solid hydrogen.

And, when the helium in its turn has capitulated, can we boast of having advanced a single serious step towards the pole of coldness which we flattered ourselves we could conquer? Not at all; because, supposing even that we could succeed at each new point in reducing one half the distance remaining, the absolute zero would still remain the last term of a decreasing geometrical progression, each of the different terms of which would only be accessible to us at the price of the struggle which has continued against helium since 1899.

And before this important capture was made of the last battalions of the thermometric scale, we should, without doubt, conclude that truly we could not really draw such pessimistic deductions from a temperature that we now conceive as still so distant from the purpose of our efforts, and, until we have more ample information, we should preserve intact our present ideas of the nature of the relations between energy and matter.

Here, then, as everywhere else, the object retreats in measure as we advance, and at no point of our science can we flatter ourselves to have touched the origin of things. But our efforts to attain it have not been the less fecund for that reason, and the science of low temperatures has, for its part, well merited of humanity, since this struggle for the absolute zero has, at the same time that it gave unlimited resources to industry, revealed to the mind horizons as extensive.

# Development of the Theory for the Kinetic Energy of Gases.

By Gustaf M. Westman, New York.

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(*Concluded from October number, p. 325*)

## DETERMINATION OF THE HEAT CAPACITY AND TEMPERATURE WHEN VACUUM AND PRESSURE DO NOT CORRESPOND TO EACH OTHER SO THAT THE FORCES ARE ALIKE.

When the vacuum and pressure correspond to each other the heat capacity is 23.

If we make the vacuum half of the size it was when vacuum and pressure corresponded to each other, and the pressure remains, the heat capacity will be altered to 16.2, as we must divide 23 with the square root of the figure, which lowers the vacuum, because both volume and pressure are necessary to constitute a force on which the heat capacity depends, and only one of them is altered.

The product of pressure and vacuum in this case is altered from 220, 364, 458 and 740 to 110, 182, 229, 370, respectively, and the energies from these ranges of pressure are 5080 Cal., 6655 Cal., 7448 Cal., and 9952 Cal., which divided by 16.2 give the reduced temperatures 314°, 410°, 460° and 614°, respectively.

These figures compare very closely with those already found, namely, 320, 413, 466 and 587. Therefore we conclude that the method of determining the heat capacity is correct, and that the lowering of the vacuum has no effect on the temperature.

It must, however, be remembered that the range of pressure cannot go below 91 atmospheres, otherwise the final temperature will not be the boiling point.

On the other hand, when the pressure is increased but the

vacuum remains, the temperature must be multiplied by the figure to which the pressure has been increased, raised to the power of 0.58 (obtained by multiplying 0.29 by 2), because the whole range of pressure is the square of the pressure.

By using these two rules for heat capacity and temperature we can determine those for any combination of vacuum and pressure.

## KINETIC ENERGY OF SUPERHEATED STEAM.

Notwithstanding that superheated steam cannot give as perfect results as the air, we will apply the same method used for air, when we will come to some interesting facts.

The heat capacity for superheated steam is 6.5 cal. per molecule, from which is deduced $\frac{k-1}{k} = 0.235$, and the ratio between the two heat capacities $\frac{8.5}{6.5} = 1.307$. The formula for the kinetic energy is $4 ( n^{\frac{0.235}{2}} - 1)^2 \times c_v \times 273$ Cal.

At first we will show that the heat capacity for superheated steam expanding freely, is 24 cal. deduced from $\frac{8.5^2}{3} = 24$, as the square of the heat capacity is divided equally between the three atoms composing the molecule.

When the temperature to be reduced, as, for instance, when air is used as the working substance, goes below 273°, the expansion must take place in a vacuum.

By expanding superheated steam the temperature is reduced to 373° by the reduction of the pressure alone, as indicated by the temperature of saturated steam, which in practice requires but a few degrees to become superheated steam. A special column for the temperature thereof is given for comparison under the heading, Saturated Steam.

For this reason we estimate the reduced temperature by the kinetic index of the pressure alone, multiplied by 373° and divided by 1.307.

It is, however, supposed that the temperature cannot go below the boiling point before all the latent heat is taken away.

We can estimate the relation between pressure and vacuum for steam in the following manner: The molecule of steam

moves in a perfect circle, different from air, which enables us to calculate the vacuum for the kinetic index in a special way.

Just as the area of a sphere divided by 4 gives the area of the circle passing through the center, so does the kinetic index for the range of pressure divided by 4 give the kinetic index for the pressure alone, which, therefore, can be equalized.

The index for the pressure is $4\,(n^{\frac{0.235}{v}} - 1)^2$ and the index for the range of pressure divided by 4 is $(x^{\frac{0.235}{v}} - 1)^2$.

For instance, at 7 atmospheres' pressure the kinetic index is $4\,(7^{\frac{0.235}{v}} - 1)^2$, and if this is made equal to $(x^{\frac{0.235}{v}} - 1)^2$, x will equal 34 and $v = \frac{34}{7} = 4.86$

In the same way the ranges of pressure and volume are calculated in the following table, which contains the reduced temperatures and a comparison of the temperatures of superheated and saturated steam. For this estimate it is necessary that the molecule shall be a perfect sphere, as in steam, which contains 3 atoms, which is not the case with air, containing 2 atoms:

| Pres. | Range of Pres. | Vacuum. | Reduced Temp. | K. Temp. | Temp. of Sat. Steam. |
|---|---|---|---|---|---|
| 7 | 34 | 4.86 | $\frac{0.264}{1.307} \times$ 373 | 440° | 437° |
| 8 | 42 | 5.25 | $\frac{0.302}{1.307} \times$ " | 461° | 442°.5 |
| 9 | 51 | 5.67 | $\frac{0.343}{1.307} \times$ " | 472° | 447°.4 |
| 10 | 59 | 5.9 | $\frac{0.388}{1.307} \times$ " | 482° | 451°.9 |
| 13.7 | 97 | 7.07 | $\frac{0.514}{1.307} \times$ " | 521° | 466° |
| 20 | 178 | 8.9 | $\frac{0.705}{1.307} \times$ " | 575° | 484° |

It is easy to confirm the above figures about pressure and vacuum, if the relation between volume and vacuum for steam is considered.

The vacuum for steam is expressed in the following formula,

in which v represents vacuum and $v_1$, represents the compressed volume:

$$v\left(1+\frac{t}{373}\right)=\frac{1}{v^1}.$$

This formula for vacuum of steam corresponds to the formula for vacuum of air as nearly as possible if the difference in temperature between both vacuums is taken into consideration, and the temperature on which the volume depends, in the case of steam, is always above 273°; while for air it may be either above or below 273°.

We use the figures under heading, "Kinetic Temperature," and divide $\left(1+\frac{t}{373}\right)$ by p, in order to arrive at the volume $v_1$, thus presenting the following table:

| p | $v_1$ | | $\frac{1}{v_1}$ | | v | | $v\left(1+\frac{t}{373}\right)$ |
|---|---|---|---|---|---|---|---|
| 7 | $\frac{1.19}{7}=0.17$ | ; | 5.88 | ; | 4.85 | ; | 5.78 |
| 8 | $\frac{1.24}{8}=0.155$ | ; | 6.45 | ; | 5.25 | ; | 6.51 |
| 9 | $\frac{1.26}{9}=0.14$ | ; | 7.1 | ; | 5.67 | ; | 7.14 |
| 10 | $\frac{1.29}{10}=0.129$ | ; | 7.75 | ; | 5.9 | ; | 7.61 |
| 13.7 | $\frac{1.40}{13.7}=0.102$ | ; | 9.8 | ; | 7.07 | ; | 9.89 |
| 20 | $\frac{1.54}{20}=0.077$ | ; | 15 | ; | 8.9 | ; | 13.7 |

From $\left(1+\frac{t}{373}\right)=p\,v_1$ and $v\left(1+\frac{t}{373}\right)=\frac{1}{v_1}$ it follows that $\left(1+\frac{t}{373}\right)^2=\frac{p}{v}$, or that the square root of pressure multiplied by the final temperature is equal to the square root of vacuum multiplied by the initial temperature. This can be seen as follows:

| | | | |
|---|---|---|---|
| $\sqrt{7}\times 373=915$ | corresponds to | | $\sqrt{4.86}\times 444=968$ |
| $\sqrt{8}\times 373=1059$ | " | " | $\sqrt{5.25}\times 461=1055$ |
| $\sqrt{9}\times 373=1119$ | " | " | $\sqrt{5.67}\times 491=1123$ |
| $\sqrt{10}\times 373=1178$ | " | " | $\sqrt{5.9}\times 482=1171$ |
| $\sqrt{13.7}\times 373=1370$ | " | " | $\sqrt{7.07}\times 521=1380$ |
| $\sqrt{20}\times 373=1669$ | " | " | $\sqrt{8.9}\times 575=1714$ |

The above calculations can be made directly from the forces

when the molecule moves in a perfect circle, as is the case with steam. When pressure and vacuum correspond to each other, all three forces are alike, and consequently the attractive force is equal to the square root of the centrifugal force.

We measure the pressure in a straight line, notwithstanding its action is along the periphery of a circle, when steam is concerned, and thus the real pressure is 3.14 times greater than the observed.

When the attractive force acts, it induces the centrifugal forces to act, which, therefore, are in proportion to 3.14 p, consequently one of the centrifugal forces must be in proportion to the square root of 3.14 p, which also must be the case with the attractive force, as all are alike.

If the effect is used instead of forces, and as $v = \frac{1}{v_1}$, wherein $v_1$ indicates the compressed volume effected by the pressure, we can use v instead of pressure and reach the following formula: $v = \sqrt{3.14\ p}$.

Applying this formula at 7; 8; 9; 10; 13.7 and 20 atmospheres' pressure, the vacuums will be respectively 4.7; 5; 5.31; 5.67; 6.6, and 7.9 without superheating.

If the steam is superheated, either the pressure or the volume increases in both cases assumed in proportion to the increased temperature divided by 373, which alters the equation to $\sqrt{3.14\ p\ (1 + \frac{t}{373})} = v$. For respectively 7°, 19°, 24°, 30°, 45°, 91° v is altered to 4.75; 5.12; 5.47; 5.90; 6.98 and 8.82 when found to be 4.86; 5.25; 5.67; 5.90; 7.7 and 8.9.

The energy from the reduced temperature multiplied by 24 compares with the kinetic energy of our formula as follows:

| | | | | | | |
|---|---|---|---|---|---|---|
| 76 | × 24 = 1824 | Cal., | when | our formula | gives | 1874 cal. |
| 88 | × 24 = 2112 | " | " | " | " | 2188 " |
| 98 | × 24 = 2356 | " | " | " | " | 2442 " |
| 109 | × 24 = 2616 | " | " | " | " | 2697 " |
| 148 | × 24 = 3542 | " | " | " | " | 3628 " |
| 202 | × 24 = 4848 | " | " | " | " | 4970 " |

## DETERMINATION OF THE KINETIC ENERGY BY THE PRODUCT OF THE THREE NATURAL FORCES.

We will now see what the result will be if the forces for steam are separated as formerly by air, and the product of them,

$11^{0.705}$, is multiplied by the unit of energy belonging to the atmospheric pressure, after deducting the energy due to the vacuum.

The greater heat capacity of steam over air, which amounts to $\frac{65}{48} = 1.345$, must, in this case, be observed.

If the product of the forces is used in the calculations, one-third of the excess of heat capacity over the air, or $0.118 \times 546$, must be added to 546, making it 611 cal. as the proper unit of energy for the molecules of steam at one atmospheric pressure.

From this must be deducted that portion of energy which belongs to the rest of vacuum corresponding to the pressure.

For instance, 7 atmospheres' pressure corresponds to 4.86 vacuum, therefore $611\ (1 - \frac{100}{486}) = 488$ cal. must be the proper unit of energy. This unit, multiplied by $7^{0.705}$, expresses the kinetic energy.

In the same way the kinetic energy for the different pressures as above, is calculated from the product of the forces multiplied by the proper unit of energy. The results are given in the following table, with a comparison of the three methods used for its determination:

| Product of Forces. | Reactive Forces. | Principal Formula. |
|---|---|---|
| $7^{0.705} \times 484 = 1922$ Cal. | 1824 Cal. | 1874 Cal. |
| $8^{0.705} \times 496 = 2148$ " | 2122 " | 2188 " |
| $9^{0.705} \times 503 = 2392$ " | 2356 " | 2472 " |
| $10^{0.705} \times 504 = 2555$ " | 2616 " | 2697 " |
| $13^{0.705} \times 521 = 3329$ " | 3542 " | 3628 " |
| $20^{0.705} \times 544 = 4500$ " | 4848 " | 4970 " |

The last formula depends on the pressure, to which a proper vacuum must be accessible in order that the forces should be even, which is a necessary condition for it, and is therefore not available under other conditions. Our principal formula for the kinetic energy, however, which depends on the range of pressure, can be used under all circumstances.

To show that the energy of superheated steam expanding against the atmosphere corresponds to our formula, we present the following table, in which the temperature at the beginning of the expansion is marked $T_1 = (\frac{\text{kinetic index}}{1.307} + 1)\ 373$, and

the temperature at the end of the expansion is marked $T_2 = T_1$ — the reduced temperature.

As the temperature begins at 373° instead of 273°, corresponding to one atmosphere's pressure, we have here to divide the index by the product of 1.367 and 1.307 = 1.78 in order to obtain the adiabatically reduced temperature.

| Pres. | Kin. Index. | $\frac{\text{The same Ind.}}{1.78}$ | Reduced Temp. | $T_1$. | $T_2$. |
|---|---|---|---|---|---|
| 6 | 0.212 | 0.119 | 44.3° | 433° | 389° |
| 9 | 0.348 | 0.196 | 72° | 472° | 400° |
| 12 | 0.456 | 0.264 | 95° | 503° | 408° |
| 16 | 0.592 | 0.332 | 124° | 542° | 418° |

| Pressure. | Energy from Reduced Temp. | Energy from Formula. |
|---|---|---|
| 6 | 44.3 × 8.5 = 376 cal. | 0.212 × 1775 = 370 cal. |
| 9 | 72 × 8.5 = 612 " | 0.348 × " = 617 " |
| 12 | 95 × 8.5 = 807 " | 0.456 × " = 809 " |
| 16 | 124 × 8.5 = 1054 " | 0.592 × " = 1050 " |

$pv^{1.307}$ is about 0.69 during compression, but not constant during expansion.

When our formula is proved to be correct by two such different gases as air and steam, it is reasonable to suppose that this formula will hold good for other gases, even if special rules have to be found governing the temperature and heat capacity.

We will only add that the whole latent and sensible heat is converted into kinetic energy, when the range of pressure is the product of the number of molecules per cubic metre and 22.3.

The great difference between using air instead of steam for motive power is that the temperatures are reduced to 193° below zero by the air, whereas the reduced temperature in the case of steam is 100° above the zero point.

For kinetic energy it is necessary to use matter in gaseous state, and the whole amount of latent heat must be supplied for making steam, out of which only a fraction is recovered as work.

If to this is added that the steam takes 50% more pressure than air for the same quantity of power, the disadvantage of the former system is clearly shown, and can be expressed as follows: As matter is nothing but enclosed energy, and as it is desired to liberate the power to produce kinetic energy, it is better to use gaseous elements and not compounds, in which a part of the energy is already taken away.

As the temperature 193° below zero has been observed by

Prof. G. A. Hirn in his experiments with rarefied air, without any work being performed, there is no question that this temperature will follow when work is done.

By closer examination of the figures for the kinetic energy, it can be found that the energy for air, divided by the square root of the range of pressure, gives a constant figure; namely, 500 cal. per molecule; whereas the energy of superheated steam, divided by the square root of the range of pressure, varies from 320 cal. to 370 cal. per molecule between 34 and 100 atmospheres' range of pressure, but above this is constant 370 cal.

| Air. | Superheated Steam. |
|---|---|
| $\frac{4436}{\sqrt{91}} = 466$ | $\frac{1874}{\sqrt{34}} = 321$ |
| $\frac{7360}{\sqrt{220}} = 500$ | $\frac{2188}{\sqrt{42}} = 338$ |
| $\frac{9530}{\sqrt{363}} = 500$ | $\frac{2442}{\sqrt{51}} = 342$ |
| $\frac{10750}{\sqrt{460}} = 500$ | $\frac{2697}{\sqrt{59}} = 351$ |
| $\frac{13570}{\sqrt{740}} = 500$ | $\frac{3628}{\sqrt{97}} = 368$ |
| | $\frac{4970}{\sqrt{178}} = 372$ |

This makes $\frac{500}{370} = 1.26$, or 26% more energy from air than from steam for the same amount of range of pressure.

### Actual Test of the Formula.

We will illustrate our formula for steam by the experiments made by De Laval Steam Turbine Co. At a pressure of 13.6 atmospheres and a bacuum of $\frac{1}{10}$ atmospheres' pressure, which latter corresponds to 5.9 vacuum, the velocity of the steam was found by several tests to be 4000 feet, or 1220 metres per second.

The energy per kilo of steam is $\frac{1220^2}{19.6}$, divided by the mechanical equivalent of heat, 426. This makes 179.4 cal. per kilo, or 3229 cal. per molecule.

The product of pressure and volume is 80.34, while the formula gives $4\,(80.34^{\frac{0.235}{2}} - 1)^2 \times 1775$ cal. $= 3195$ cal.

## VELOCITY OF GASES.

Finally, we will show that the formula for the kinetic energy of gases is in accord with the velocity of the molecules. To this end we must first abandon the generally accepted theory thereof, which says that the gas molecules at ordinary pressure are free to move in rectilinear directions, because they do not exert any mutual effects upon each other, except at extremely small distances.

In opposition to this theory we assume that the molecules move in circles inside the ether at atmospheric pressure, when no difference in pressure exists, but takes a forward motion when the pressure goes from a higher to a lower point. We will show that this forward motion is a circle whose diameter is equal to the square root of the kinetic index multiplied by 2 or 3, according to the number of atoms in the molecules, each atom giving its own impetus to the motion.

This forward motion, however, has nothing to do with the ordinary rotatory motion at one atmosphere, which continues just the same.

On the other hand, the forward velocity shows itself to be in proportion to $3.14\ g^2$.

For 91 atmospheres' range of pressure the energy is 4436 cal. per molecule, or 154 cal. per kilo., consequently $154 \times 426 \times 19.6 = v^2$, if v is the velocity and 426 the equivalent of heat in kilogrammeters. This makes $v = 1133$ meters. In the same way the velocities are found for different ranges of pressure. With velocities calculated in this way we compare, in the following table, the velocities or the diameters of the circles in which the molecules move.

Applying this to the air we must add two per cent. on account of the molecules moving in ellipses instead of circles,

which makes the product of 3.14 .96; 2 (+ 2 per cent.) = 308.

WITH VACUUM.

| Range of Pres. | Energy per Ko. | Velocity. | Index to K. E. | Diameter. | Diam. x 308 |
|---|---|---|---|---|---|
| 91 | 154 cal. | 1133 meters | 3.40 | 2× 1.84 | 1133 met. |
| 220 | 254 " | 1460 " | 5.66 | 2× 2.37 | 1460 " |
| 363 | 330 " | 1660 " | 7.29 | 2× 2.67 | 1645 " |
| 460 | 371 " | 1760 " | 8.2 | 2× 2.86 | 1762 " |
| 740 | 470 " | 1986 " | 10.36 | 2× 3.31 | 1978 " |

WITHOUT VACUUM.

| Pressure. | Energy per Ko. | Velocity. | Index of K. E. | 2 Diameter. | 2d D. x 308 |
|---|---|---|---|---|---|
| 6 | 16.1 cal. | 365 | 0.347 | 2 × 0.591 | 364 |
| 9 | 21.5 " | 471 | 0.584 | 2 × 0.764 | 471 |
| 12 | 33.5 " | 529 | 0.74 | 2 × 0.86 | 530 |
| 16 | 43.5 " | 603 | 0.96 | 2 × 0.94 | 603 |

The same calculation for superheated staeam gives the following results:

WITH VACUUM.

| Range of Pres. | Energy per Ko. | Velocity. | Index of K.E. | 3 Diameter. | 3 D x 302 |
|---|---|---|---|---|---|
| 34 | 104 cal. | 932 | 1.06 | 3 × 1.03 | 931 |
| 42 | 122 " | 1010 | 1.23 | 3 × 1.11 | 1004 |
| 51 | 136 " | 1066 | 1.376 | 3 × 1.175 | 1058 |
| 59 | 150 " | 1120 | 1.52 | 3 × 1.235 | 1116 |
| 97 | 202 " | 1300 | 2.04 | 3 × 1.43 | 1293 |
| 178 | 265 " | 1483 | 2.80 | 3 × 1.676 | 1514 |

WITHOUT VACUUM.

| Pressure. | Energy per Ko. | Velocity. | Index to K.E. | 3 Diameter. | 3 D x 302. |
|---|---|---|---|---|---|
| 6 | 20.6 cal. | 416 | 0.212 | 3 × 0.461 | 417 |
| 9 | 34.5 " | 537 | 0.348 | 3 × 0.59 | 535 |
| 12 | 45 " | 613 | 0.456 | 3 × 0.673 | 612 |
| 16 | 58.3 " | 698 | 0.592 | 3 × 0.77 | 697 |

If we calculate the diameter for the different volumes, we find that the molecule rotates inside the gas volume.

Notwithstanding that the velocity is derived from the square root of the constant in our formula, multiplied by 2 or 3 times the square root of the kinetic index equal to the diameter of the circle in which the molecule moves, we have executed our examples in order to show that the ordinary rotatory velocity of the molecule goes out of the equation for a change of pressure from a higher to a lower point, and thereby the forward motion is independent of it.

It is easy to see this during compression, because the velocity

stands in direct proportion to the square root of the pressure, which for one atmosphere goes out of the equation. During expansion, however, this must be shown by figures.

To show the ordinary rotatory velocity of the molecule during expansion, we make $4\,(n^{\frac{k-1}{sk}}-1)^2=1$, whereas this rotatory velocity is calculated by $2 \times 308$, equal to 616 meters for air, and $3 \times 302$ equal to 906 meters for steam.

If it is assumed that the height of one homogeneous atmosphere of air at 273° absolute temperature is 8000 meters, and the height of one homogeneous atmosphere of steam at 373° absolute temperature is 17,300 meters, the absolute velocity would be $\sqrt{2g \times 8000}=395$ meters, and $\sqrt{2g \times 17{,}300}=580$ meters in a straight line, which has to be multiplied by 1.57 in order to have the velocity in the periphery, because the velocities are carried over from one molecule to the other, thus making them respectively 620 and 910 meters.

The velocities in all our examples for air and steam, where the expansion is against the atmosphere, do not go as high as this ordinary rotatory motion of the molecule, and consequently this ordinary rotatory motion is not in the equation.

The difference between these two motions is, that the diameter of the forward motion is represented by the actual figures in meters, while the diameter, in the ordinary rotations of the molecules of atmospheric pressure, depends on the actual size of the molecule.

Main results: That the heat capacities of the kinetic energy in vacuum for air and steam are constant $\frac{c_v^2}{2}$ and $\frac{c_v^2}{3}$, respectively, and the work is in proportion to the reduction in temperature, which is in harmony with the potential energy.

That the kinetic energy divided by the square root of the range of pressures is constant; namely, 500 cal. for air, and 370 cal. for superheated steam.

If these figures are multiplied by their respective heat capacities, the products will be equal, $4.8 \times 500=6.5 \times 370$. Therefore, and for the reason that log. $c_v^{\frac{k-1}{k}}$ is constant, we conclude that the kinetic energy is in inverse proportion to the heat capacity. We assume this rule is true for all gases, wherefore

the energy for one molecule, or 22.3 cub. met., of any gas is $\sqrt{n} \times 500 \times \frac{4.8}{c_v}$ cal., wherein n is the range of pressure and $c_v$ the heat capacity for the molecule in question.

That the velocity of the kinetic energy for all gases is in direct proportion to $3.14\ g^2$ at all pressures and vacuums.

The kinetic energy of the gas is consequently in proportion to $3.14^2 \times g^3$, which shows that the acceleration belongs not only to the attractive force, but also to the centrifugal forces.

If to this is added that the unit of energy multiplied by the product of the three natural forces in all instances, no matter what their strength is, conforms with our formula, there cannot be any doubt of its correctness, as most physical formulas rest on units, and numerical figures therefrom are accepted as facts.

The following facts have been demonstrated by our formula, which would not have been the case if the formula was incorrect; namely, for air: That the square of the initital pressure, multiplied by the final temperature, is equal to the square of vacuum multiplied by the initial temperature, and for steam; that the square root of the initial pressure, multiplied by the final temperature, is equal to the square root of the vacuum multiplied by the initial temperature;

That the heat capacity is constant 23 and 24, when pressure and vacuum correspond to each other.

This rule cannot be applied to superheated steam where the range of pressure is less than 100 atmospheres.

By explaining the actual relation between pressure and vacuum, the generally accepted theory that the molecules move in rectilinear courses, is rendered untenable, and the real motion is found to be a rotary one.

As to the kinetic energy of gases, we have to deal with three variables and one constant, which also changes under certain conditions. These variables go from one extremity to the other, and must be determined at the beginning and at the end of expansion. Consequently at least six determinations must be made for every problem.

Through our formula only the product of pressure and vacuum can be determined, and the difference in temperature when the heat capacity is known.

Special rules must, therefore, be found to determine the rela-

tion between pressure and vacuum and the heat capacity, if needed.

When vacuum is used the final temperature is at the boiling point, and in case the expansion is against one atmosphere, the initial temperature can be determined by adiabatic compression.

Convinced that our theory for the kinetic energy of gases is in accord with facts and fully established, we make the following remark:

The formula is deduced from our principal energy-formula, under which law the energies of solid and liquid bodies are governed, consequently the latter, either directly or indirectly, can be considered as the ruling formula to determine the energy at every change of volume for any body.

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ERRATA, October number:—In "Development of the Theory for the Kinetic Energy of Gases," by Gustaf M. Westman. Page 317, eleventh line, read "two equal forces," instead of two equal force; page 319, seventh line, read $4\,(n^{\frac{k-1}{k}} - 1)^2$, instead of $4\,(n^{\frac{k-1}{2k}} - 1)^2$; same page, thirteenth line, read $4\,(n^{\frac{k-1}{2k}} - 1)^2$, instead of $4\,(n^{\frac{k-1}{k}} - 1)^2$; page 320, eighth line, read "in vacuum," instead of is vaccuum; page 321, thirty-third line, read $4\,(n^{\frac{k-1}{2k}} - 1)^2$, instead of $4\,(n^{\frac{k-1}{k}} - 1)^2$; page 322, twenty-fifth line, read 493°, instead of 393°; page 323, twelfth line, read "n is the range of pressure," instead of n is the pressure; same page, thirty-third line, read "logarithmic spiral," instead of ligarithmic spiral.

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## ZINC INDUSTRY IN UTAH.

The zinc ore product of the Park City district in Utah fell off heavily in 1905 through the caving-in of the Ontario drain tunnel, says Mr. Charles Kirchoff of the United States Geological Survey in a forthcoming report on the production of zinc. A mill equipped with the Blake-Morscher electrostatic separators was put into commission during 1905 at Salt Lake City. At Frisco the Horn Silver Company shipped a considerable tonnage of zinc ore to the Iola works. There has been some talk of building a zinc works at Bonneville, twelve miles north of Ogden.

## THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

Announcement has been made of the programme of the fourth congress of the International Association for Testing Materials, which will be held in Brussels, Belgium, September 3-8, 1906. At the general meeting on Monday, September 3, a commemorative speech in honor of the late president, Professor Tetmajer, will be made by Prof. F. Schüle, and there will be a lecture on the industries of Belgium. Section meetings will be held on Tuesday and Wednesday forenoon, with visits in the afternoon to places of technical interest in Brussels and vicinity. There will be a general meeting on Thursday, with reports of sections, and on Friday a visit to the works of the John Cockerill Company, Seraing. The delegates will visit the Harbor Works in Zeebruge on Saturday. It is stated in the report of the council that the membership on January 1, 1906, was 1814, as against 2200 in the preceding year. The decrease is attributed to the withdrawal of American members, the number from this country having fallen from 600 to 241 in consequence of the action taken at the 1905 meeting of the American Society for Testing Materials in raising its membership fee to $5 and leaving its members free to take membership in the International Society as individuals. Previously a portion of the $5 fee of each member of the American Society had been sent to the International Society.

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## FERROCYANIDE TITRATION.

It is commonly recommended, in titrating ferrocyanide with zinc sulphate, to determine the end point by placing on a piece of iron free filter paper; first a drop of the liquid examined, and then a drop of (acidified) ferric chloride solution. The end point is reached when a blue streak ceases to form after a minute or two at the junction of the two drops. In the *Zeit f. Angew. Chemie*, 1906, p. 615, D. Stavorinus points out that the test may be simplified by using Schleicher & Schüll's filter No. 598, which contains a trace of iron. With this the use of ferric chloride becomes unnecessary, the blue coloration appearing after a minute or two owing to the iron in the paper.

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## EFFECT OF STRAINS IN COLD-WORKED IRON.

Strains in cold-worked iron or steel may be detrimental. A piece of straight, cold-drawn shafting, if machined, as for instance in key seating or in turning, is very liable to be not straight after the machining, as cutting away a part of the strained metal removes part of the stresses, and those remaining cause the resultant effect to be different from what it was, and the new adjustment necessary is found in a new shape of the piece.

## Mechanical and Engineering Section.

*(Stated Meeting, held Thursday, October 11th, 1906.)*

# The Application of Mechanical Refrigeration to Ice Cream Manufacture.*

By Jos. H. Hart, Ph.D.

The application of mechanical refrigeration to the manufacture of ice cream is one of the developments of the last few years which is destined to become very much more prominent in the near future. The manufacture of ice cream has always been considered rather a small business, requiring small capital, and from its very nature necessarily constrained to exist in rather small units. This is still true in many sections, but changes are rapidly taking place, and there exist at present considerably over a score of large ice cream factories each of whose output requires from 50 to 100 tons of ice daily in its manufacture during the summer months. In some localities, whole states are supplied from a common center, and the number of factories in this class is rapidly increasing. Remarkable as it may appear to the refrigerating engineer, in nearly every case, this ice is purchased in the open market, and antiquated methods of manufacture exist everywhere and nearly every large plant remains practically a collection of small units under a common roof. But a change has commenced, and the reason for this change and the reason that it has not come sooner is easily determined.

To see this clearly, we must understand the old methods of ice cream manufacture, their advantages and disadvantages, and the conditions that must be met in a modern refrigerating plant used for this purpose. The use of cyrohydrates, of which ice and salt is one of a large class, as a method of refrigeration is one of the most wasteful and uneconomic processes known in engineering physics, and is not in the same class with

*Read by title.

a modern ammonia machine. It has been superseded in practically every refrigerating line save that of ice cream production and the reason for this is two-fold. As has been said before, ice cream factories, until recently, have always existed in small units, and the waste, although relatively large, was practically small. Percentage profits were large, but the amount of sales did not warrant a large outlay and the capital and skilled labor required for any other process. In the second place, and this is a difficulty still very prominent, the utilization of any other method of refrigeration for the production of ice cream did not eliminate totally the use of ice and salt, which must still be used for packing and shipping. A number of the large ice cream plants have installed refrigerating machines, the majority to produce their own ice and cold brine entirely, but some few freeze only with machines and buy their ice for packing and shipping.

It is thus seen that a refrigerating plant for ice cream making is an ice making plant primarily, with slight modifications for freezing and storing the cream, but not subject to the limitations enforced in commercial ice manufacture due to the use of distilled water and the construction of the ice in large cakes freed from air. There are other limitations affecting the capacity of the compressor, etc., which can best be understood by a review of the process of manufacture from the taking in of the raw material to the output of the finished product.

The cream, immediately on arrival at factory, is put in cold storage chambers and cooled to about 35° Fahr. and kept at that temperature for several days if necessary. It has been found that a certain amount of ripening of the cream is beneficial both to the taste and consistency of ice cream, and there is a very marked deterioration with use of fresh cream. This ripening can be hastened by the use of lactic ferment and cream ripening machines such as are used in dairies for butter manufacture. These machines, which are made by the Creamery Package Co., are very useful and save considerable time, but are not in general use, except in the larger ice cream factories, most firms buying cream of the required ripeness or allowing it to attain this by standing. When the cream is ready for use it is taken to the mixing room, where the various ingredients are thoroughly mixed, often by hand, and then

taken to the freezer. There are a number of different types of freeezers, and recently a number of new continuous freezers have been invented and put on the market, but they are not used to any great extent and have not proved very satisfactory. The ordinary household freezer is well known and is the common type used in large factories with slight modifications. They are generally in 40 quart units and are belt driven, and are cooled by ice and salt or cold brine, which may come from an ice and salt tank or from an ammonia refrigerating system. There has been one quite recent improvement, however, which bids fair to be of permanent value and which is the main feature of the Emory Thompson Brine Freezer. In this freezer, the power is applied continuously and means are devised for emptying and filling the freezer without stopping the machine, and the advantage is so great that it is being installed in all modern plants. It takes from 12 to 15 minutes to freeze a 40-quart batch of cream with the ordinary freezer. Cream swells in the freezing and it is customary to double the output by this process. Thus 17 quarts of the mixture will become 34 quarts of ice cream in the ordinary time of freezing, but it is possible to increase this output to 40 quarts by freezing for about 23 minutes, although the liability of buttering the cream by this process is much increased. The freezer serves a three-fold purpose; it cools and partially solidifies the cream, it thoroughly aerates it and produces the swell, and finally, it thoroughly mixes the cream, smoothing out the lumps and grains and hastening the process of freezing at the same time by bringing new material constantly in contact with the cold walls.

Contrary to general belief, the cream is not frozen in the freezer. Cream begins to thicken from the cold at about 25° Fahr. It has no definite freezing point, but is considered hard at from 6° Fahr. to 8° Fahr. It is put in the freeezer and cooled to about 15° Fahr. It can still be poured in large masses at this temperature, but is thick enough to retain air bubbles and to stand without settling for some time. The temperature of the ice and salt rarely falls below 3° Fahr. or 4° Fahr. below zero and is generally variable throughout the mass, so that the use of brine is preferable if for this reason only, as its temperature is nearly uniform. With an ammonia machine for cooling the brine, it is generally carried about 10°

Fahr. below zero, and this permits six or seven batches to be made in an hour, while the ordinary freezer only allows four or five batches at the most in the same time.

The cream is taken from the freezer and carried to a setting tank where it is kept at a temperature of about 10° Fahr. below zero for from two to four hours and frozen solid. If the brine system is used, the brine for the setting tank is carried on the same circuit with the freezers. If ice and salt only is used, it is put in shipping packages and kept sometimes for as much as eight hours, with constant renewals of ice and salt until shipped. The setting tank consists of an insulated brine tank with a framework to hold the cans of ice cream and a special arrangement to prevent the flooding of the cream with brine.

Now, in regard to the quantity of ice and salt used in making ice cream, or the refrigeration necessary for the production of ice cream in bulk. In practice it takes about 150 pounds of ice and about 40 pounds of salt to make one 40-quart batch of cream. Of course, these figures are cut down considerably when cream is made continuously, but a smaller retailer will use 300 pounds of ice a day to make and store 40 quarts of cream and between 800 and 900 pounds to make approximately 100 quarts of cream and keep it. The great cost is the shipping expense, and this depends on the size of shipping packages. Large concerns have been able to get the total ice consumption for manufacture, storage, and packing for shipment, down to between 400 and 500 pounds of ice per 40-quart can of ice cream, the variation being dependent on the average size of shipping packages. The quantity of ice used for manufacture is much smaller when cream is made continuously, so when figures are desired on refrigeration for a plant, it is best to neglect this factor and consider 50 pounds of ice per gallon of ice cream necessary for shipping purposes alone, in plants having an output of not less than 1,000 gallons of ice cream per day.

Now, in regard to the thermal properties of ice cream itself and the amount of refrigeration necessary in its manufacture.

In a 40-quart batch about 16 quarts of cream are taken, four quarts of condensed milk, and sugar and flavoring and some kind of thickener sufficient to make about 22 quarts. This is sufficient to make ten gallons of ice cream. It weighs

between forty-five and fifty pounds. It has a specific heat varying between .70 and .80 B. T. Units. Its latent heat is indefinite as it does not freeze at any fixed temperature, but gets thicker and harder as it gets colder and is practically solid at about 6° Fahr., beginning to solidify at about 25°Fahr. The total heat of cream between 70° Fahr. and 32° Fahr. varies from 25 to 30 B. T. Units, between 32°Fahr. and 6° Fahr. it varies from 85 to 95 B. T. Units per pound of the mixture. The water ices are considerably higher, ranging from 150 to 170 B. T. Units as the total heat from 70° Fahr. to 6° Fahr. per pound, and it is better to take this higher figure in computing refrigerating values. Of this heat, 100 B. T. Units are absorbed in the cooling room to lower to about 35° Fahr., 600 B. T. Units in the freezing process or in the manufacture itself, and 200 B. T. Units in the setting tank per gallon of cream. The two latter figures change somewhat, depending on the manufacture of water ice or ice cream, but the total remains the same. Fifty pounds of ice absorbs 7,100 B. T. Units and it is generally assumed that it takes an absorption of twice this number of B. T. Units to make this much ice, say roughly 14,000 B. T. Units. If we allow 50% loss by radiation in the manufacture of ice cream, due to the low temperature carried and to the fact that insulation is seldom carried on a freezer, we have a total of about 15,000 B. T. Units per gallon of ice cream, of which approximately 10% is used in freezing and storing the cream.

Now, ice is usually made at a brine temperature of from 15° Fahr. to 19° Fahr. This corresponds to an ammonia temperature of zero Fahr. of the suction gas. In order to maintain twenty pounds (Gauge). The capacity of a compressor is generally rated at fifteen pounds suction pressure and a temperature of O° Fahr. of the suction gas. In order to maintain a brine temperature of 5° Fahr. below zero, the suction gas is kept at a temperature of 17° Fahr. below zero, and this means a suction pressure of less than five pounds. This means that a machine must be cut down to three-quarters of its normal rating and considered at about one-half of its ice making capacity when used for this purpose. Besides, the ratio of useful to total work is much diminished when run at this pressure, and the fuel cost per

ton correspondingly increased, and this in the face of the fact that only about 10% of the refrigeration is required at this temperature and the remainder could be used in a normal ice making plant. This problem has been attacked in a number of ways. Some firms have small refrigerating plants to freeze and set the cream only and buy their ice for shipment. This eliminates the mess and trouble in making the cream, but is not economical unless labor and power are at hand for other purposes and do not enter as large cost factors. The ice and salt must be supplied for shipment and there is not much difference in the total cost and mess and labor with ice and salt whichever method is used. Another method is to have a separate ice making plant and use this ice to make the brine for the freezers and setting tank.

There is no doubt that it pays for even a small ice cream manufacturer to make his own ice. He does not use filters and has no need of distilled water. He can use a gas engine as a source of power and generally has this on hand or needs it to run the freezers and the ice crusher, and needs no more labor to attend to both. He can use the excess labor about the place to draw ice as it is needed, and can have on the same brine system a cold storage room to cool the fresh cream and to store the packed cream before shipment. There is no extra office or management expense and the ice can be made in small blocks very rapidly. An extra brine storage tank could be pressed into service at night and much of the danger of packing and setting at night in the hot summer months could be eliminated, and the plant shut down at night without special preparation.

A number of larger firms use refrigerating machines entirely, for the freezing and setting of the cream, cold storage room, and the making of ice for the packing and shipping, and all this on the same brine circuit in spite of the diminished capacity and increased cost of operation of the plant, consequent to the use of this low temperature. The truth of the matter is that the use of ice and salt is so wasteful and costly, that it is difficult under almost any circumstances, to find anything that can compete with it in this direction. The ice cream manufacturer pays in the open market from one to two dollars a ton for ice delivered, and a number use from sixty to eighty tons a day

in the summer months, and about one-quarter of this weight in salt at a cost of ten to twelve dollars a ton for the salt. In one or two factories, two separate refrigerating systems are used and this of course solves the problem although increasing the cost considerably. The use of a small auxiliary compressor cooling a separate brine system for the freezer and setting tank, and compressing into the suction side of the main ice making compressor has been suggested but never tried, although it could be run with considerable efficiency as the pressures on both sides are low.

We have been speaking hitherto about the wholesale ice cream manufacturers. Now, there are a large number of department stores, restaurants and hotels use from one hundred to two hundred gallons of ice cream every day and make it by the ice and salt method. The shipping cost is not a factor to these men, and there is a distinct advantage in the use of mechanical refrigeration. It takes from one and a half to two tons of ice a day to make and keep one hundred gallons of ice cream by the old method and between four hundred and five hundred pounds of salt. If they have their own refrigerating and ice making plant in the place for other purposes this is not so bad, but a special plant for ice cream will still pay. One ton refrigeration will keep cold about 200 cubic feet of well insulated space, if held at zero Fahr., in rooms of less than 1,000 cubic feet capacity. Accurate figures for setting tanks at 10° Fahr. below zero are not known. A settling tank of about sixty cubic feet is ample room for 150 gallons of cream, and with an unprotected brine freezer, one ton refrigeration seems necessary to keep the system in normal working order. The one hundred gallons of cream take roughly half a ton refrigeration, and this is to be made in the day-time and stored at night, so that this seems to be about the limit of a three-ton compressor. Of course, it may stand an overload, exactly as ordinary systems do, but it is best to figure on a three ton for this service and a five ton for 200 gallon, and this is about the limit required for the amount of cream used under such conditions.

## Sections.

*(Abstract of Proceedings.)*

MINING AND METALLURGICAL SECTION.—*Stated meeting* held Thursday, October 4th, 8 P.M. Mr. James Christie in the chair. Present seven members.

The paper of the evening was presented by Prof. A. E. Outerbridge, Jr., on "Recent Progress in Metallurgy." The speaker reviewed the numerous advances made in various branches of the science, and gave an instructive summary of the remarkable industrial results accomplished during the past year.

The Chairman tendered the thanks of the meeting to the speaker and the session was adjourned.

WM. H. WAHL, *Sec'y pro tem.*

SECTION OF PHYSICS AND CHEMISTRY.—*Stated meeting* held Thursday, October 11th, 8 P.M. Dr. Edward Goldsmith in the chair. Present, nineteen members.

The Chairman introduced Dr George F. Stradling, Prof. of Physics in the N. E. Manual Training School, Philadelphia, who presented a paper on "The N-Rays and Other Allied Rays." The communication was, substantially, a critical review of the extensive literature of the subject. It was freely discussed.

A paper on "Tax-free Alcohol," presented by Mr. Albert P. Sy, and one by Dr. Edward Hart, on "The Application of Refrigeration to Ice Cream Manufacture," were read by title, and referred for publication. Adjourned.

W. J. WILLIAMS, *Secretary pro tem.*

## Committee on Science and the Arts.

*(Abstract of proceedings of the stated meeting held Wednesday, October 3d, 1906.)*

MR. HUGO BILGRAM in the chair.

The following reports were adopted:

(No. 2374.) *Improvements in Analytical Methods and Apparatus.* Dr. G. H. Meeker, Philadelphia.

ABSTRACT: The inventions and improvements in analytical apparatus and methods embrace the following items:

The *Micro-burette:* This device consists of a small, accurately graduated burette provided with a combined stop-cock and stirring rod, permitting the addition and mixing of very small and measured amounts or reagents to samples of liquids contained in small vessels, such as test-tubes. The improvement affords a convenient means of volumetric testing on a small scale.

*Apparatus for Centrifugal Analysis:* This apparatus includes a special vernier caliper and an improved quantitative tube, by which means a fine

graduation of the space holding the precipitate is made possible. The tubes graduated by this method have been employed for the determination of chlorides, sulphides, phosphates and dextrose in urine, and the results obtained are reported to be extremely accurate.

*Apparatus for the Determination of Urea:* This apparatus resembles closely some of the well-known forms of carbon dioxide apparatus by the Fresenius-Will method. The report states that it is very well adapted for its intended purpose.

*The Synthescope* is a simple contrivance which permits the ready observation of reactions occurring at the contact surface of two liquids, *e. g.*, the precipitation of albumen by the action of nitric acid upon urine containing small amounts of this substance. It is a glass tube, the lower end of which is drawn out to a fine point, which is curved so that the liquid discharged from it passes upwards forming a layer above the point of discharge. The apparatus is admitted to give excellent results.

Improvement in the *Babcock Milk-fat Test:* This consists in the addition of a special mixing chamber for the sample and added acid. The report states that by this addition the manipulation of this method is somewhat simplified.

*Balances for Weighing Bulky Objects:* The weighing of bulky objects is effected practically in the same way as in balances used for the determination of the densities of gases.

The instrument, intended for very fine or "critical" work, is essentially a small analytical balance embodying some of the features of the assay balance.

In addition to the foregoing, the applicant submitted for investigation certain *Improvements in Analytical Technique:* These include (a) the sampling of urine by means of the centrifuge; (b) the filtration of certain urines; (c) the testing of urine for sugar by means of phenylhydrazine; (d) various improvements in handling Dare's hemoalkalimeter; (e) a simple method of determining slight changes in the color of litmus paper; (f) a ready way of making the iodoform test for acetone in urine; and (g) the volumetric determination of chlorides in urine.

The sub-committee finds that all of these devices and methods exhibited more or less novelty and utility, in recognition of which the Committee awarded the Edward Longstreth Medal of Merit. [Harry F. Keller, Chairman; W. J. Williams, William O. Griggs.]

(No. 2382.) *Etch-Powdering Machine.* Lewis E. Levy, Philadelphia.

ABSTRACT: This invention is covered by letters patent of the United States, No. 800,225, Sept. 2, 1905, granted to applicant, and has for its object the powdering of a metal plate to prepare it for the process of etching. This includes the powdering of the design on the flat surface of the plate before the first etching, and the subsequent powdering of the sides of the lines and stipples of the design after the first etch to protect them from the action of the acid in the next etch. This has heretofore been done by hand, and requires skill, good judgment and considerable labor. A complete description of this machine with illustrations will be found in this *Journal*, Vol. clxi, pp 59-69, to which the reader is referred.

The invention has been reduced to practice, and is now in successful use in several large newspaper establishments.

The Committee's report on the investigation concludes as follows:

"On account of the importance of the rapid reproduction of photographs and sketches for newspaper work, and of the advance which this machine makes in this step of the process, in addition to the admirable design of the machine, we recommend the award of the John Scott Legacy Premium and Medal to Louis Edward Levy for his machine for Powdering Plates for Etching." The report was adopted. *(Sub-Committee:* Wm. H. Thorne, Chairman; M. I. Wilbert.)

The following report passed first reading:

(No. 2379.) *Apparatus and Method for Detecting Electrical Oscillations:* Louis H. Walter, Prof James A. Ewing.

THE SECRETARY.

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# The Franklin Institute.

*(Proceedings of the stated meeting held Wednesday, October 17th, 1906.)*

HALL OF THE INSTITUTE,
PHILADELPHIA, OCTOBER 17, 1906.

MR. JAMES CHRISTIE in the chair.

Present, thirty-eight members.

Additions to membership since last report, three.

The first communication of the evening was presented by Mr. J. C. Trautwine, Jr., on the subject of "Legislative Engineering," in which the speaker severely criticised the system prevailing in Philadelphia and elsewhere whereby the local legislative bodies are permitted to interfere in the execution of engineering works. The speaker's remarks were illustrated with the aid of lantern photographs.

Prof Carl Hering followed with a description of the "Decker Primary Battery," and illustrated his remarks by an exhibition of, and demonstration with this apparatus.

On motion, the invention was referred for investigation and report, as to its merits, to the Committee on Science and the Arts.

Prof. A. E. Outerbridge, Jr., made some informal remarks on "Recent Progress in Metallurgy." His remarks were devoted chiefly to an account of the enormous growth in the production and consumption of metals—especially of iron and steel. He devoted some time to the consideration of the subject of special or self-hardening steels, which depend, for their remarkable properties, on the addition of small percentages of the rare metals, such as tungsten. He alluded also to the great advance recently made in foundry practice, whereby the texture, strength and qualities of one and the same cast-iron may be modified at will, and exhibited a remarkable specimen to illustrate his statement.

The Chairman expressed the thanks of the meeting to the speakers of the evening, and the meeting was adjourned.

WM. H. WAHL, *Secretary.*